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Feasibility of converting agrosilvopastoral systems of dairy cattle to the organic production model in southeastern Mexico

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ABSTRACT

In the municipality of Tecpatan, Chiapas, in southeastern Mexico, it is highly feasible to convert traditional agrosilvopastoral systems of dairy production to the organic production model. The objective of this study was to characterize silvopastoral systems and evaluate the feasibility of converting traditional agrosilvopastoral systems to the organic model. We studied 75 cattle farms belonging to three Rural Production Societies (RPS; rural cooperatives): (i) RPS Grijalva (RPS-G: $n = 35$), (ii) RPS Pomarroza (RPS-P: $n = 22$), and (iii) RPS Malpaso (RPS-M: $n = 18$). For this, we used as a guide the multi-criteria methodology of the Organic Livestock Proximity Index (OLPI) proposed by Mena et al. (2011), adapting it to suit our purposes. In the current study, we designed a new OLPI with 35 variables which integrate 10 indicators. Information was obtained through direct observation and a questionnaire applied to producers. Statistical analysis of the results of 10 indicators used did not show significant differences among rural production societies. The same was true for the organic conversion index ($p > 0.05$: RPS-G = 62.5%; RPS-M = 63.4%, and RPS-P = 64.6%). The data suggest that all cattle farms need to substantially improve veterinary care, safety of milking, quality of milk and dairy products, ecological management, and sustainable grassland management. In general, producers of the three rural production societies should be trained in a variety of organic cattle production and management techniques so that cattle farms may achieve a closer approximation to the organic model of production and thus may be certified.

1. Introduction

Currently, organic (ecological or biological) agriculture is increasing in importance worldwide due to the growing demand for healthy food produced in environmentally sustainable systems, given that most high-input systems are environmentally unsustainable (Pimentel et al., 2005; Pingali and Raney, 2005). Organic agriculture bases its principals on health, ecology, fairness, and care (IFOAM, 2009). Organic livestock raising is developed in animal production systems based on grazing, closing the soil-plant-animal cycle in a natural and integrated manner. This conserves the environment and biodiversity, promotes animal welfare, avoids use of chemical substances, and offers consumers animal products of high nutritional and hygienic-sanitary quality (IFOAM, 2005).

Organic production is being widely introduced to many countries due to the fact that competition for quality has become critical to marketing products; due to promotion and education, consumers are beginning to see organic products as being of greater quality. In industrialized and industrializing countries, this has led to increasing interest in comparatively evaluating productive technologies and quality of agricultural products (Stofferahn, 2009). This evaluation allows for identifying impediments to converting cattle raising systems to organic production and implementing corrective measures in order to obtain high-quality products and thus be able to compete in regional, national, and international markets, as has been reported by Niemeyer and Lombard (2003), Gonzalez and Nigh (2005) and Nelson et al. (2010).

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Organic certification of foods of animal origin leads to better options in organic markets, and allows for competition for quality niche marketing and improved prices (von Borell and Sorensen, 2004). Therefore, it is necessary to evaluate comparative advantages of agrosilvopastoral technologies and systems, as well as the quality of the resulting organic animal products.

Organic cattle raising with silvopastoral management and low levels of external inputs allows for clean production as it contributes to maximizing positive interactions among agriculture, cattle raising, silviculture, and the physical environment. It also maximizes productivity of the land; efficiently manipulates biological principles of crop and animal production; increases production; promotes wise use and conservation of natural resources; and provides a variety of environmental services (Gutteridge, 1991; Dagang and Nair, 2003; Steinfeld, 2002; Nahed et al., 2010). Evaluations of the potential for carbon capture in cattle raising landscapes of the Lacandon Jungle region of Chiapas, Mexico show greater capture in pastures with tree presence (88.89 Mg C ha^1), followed by pastures with living fences (87.5 Mg C ha^1), and monoculture pastures (60.62 Mg C ha^1; Jimenez et al., 2008). In Central America and Colombia, Ibrahim et al. (2007) report greater carbon capture in secondary forests (162.17 Mg C ha^1) than in forage banks (130.6 Mg C ha^1), pastures improved with trees (115.13 Mg C ha^1), natural pastures with trees (97.3 Mg C ha^1), and degraded pastures (72.5 Mg C ha^1). Thus cattle production systems with low inputs and high diversity provide sustainable production of bioenergy (Ceotto, 2008).

Organic cattle raising with silvopastoral management also allows for a cleaner production than pastoral systems because it contributes to reducing enteric methane emissions. Less methane is emitted when animals consume forage which is easily digestible than when they consume forages of low digestibility (Blaxter and Clapperton, 1965; McCrabb, 2002). Organic cattle raising with silvopastoral management emits less methane because foliage of forage tree species are more highly digestible than grasses. Thus, i) in vivo digestibility of the grass *Pennisetum clandestinum* (36.9%) as the sole diet of sheep was lower than that of a diet with 40% *P. clandestunum* and 60% foliage of the tree species *Buddleia skutchii* (42.3%; Sangines et al., 2007), and ii) in situ digestibility of grasses *Pennisetum purpureum* (70.1%) and *Cynodon nlemfuensis* (53%) was less than that of the foliage of the tree species *Gliricidia sepium* (74.1%), *Brosimum alicastrum* (84.8%), *Erythrina mexicana* (75.8%), *Guazuma Ulmifolia* (77.9%), and *Cajanus cajan* (73.3; Jimenez, 2000). In this manner, organic cattle raising with silvopastoral management contributes to reducing methane emissions and mitigating climate change.

In the area of south-eastern Mexico studied (the State of Chiapas), almost all cattle raising is characterized by extensive grazing, which is a principal requisite for transitioning toward organic production. In rural farm communities in the Mesoamerican Biological Corridor (an area of great biological diversity) such as those of this study, livestock raising follows a scheme of traditional agrosilvopastoral management, as animals feed in pastures with varying concentrations of dispersed trees. However, it is necessary to identify limits, potentials, and opportunities of these traditional agrosilvopastoral systems in order to guide them toward organic certification.

According to INEGI, in 2007 Chiapas had 1,406,000 head of cattle, which occupied 1,427,000 ha of pasture land (INEGI, 2007), with a predominance of extensive production systems and few semi-intensive and intensive cattle farms. In Chiapas in 2008, these cattle systems produced 209,179 tons of live animals, 107,505 tons of meat carcass, and 366,393,000 L of milk (SIAP, 2008) which were distributed locally and nationally. In the municipality of Tecpatan, producers sold 4765 tons of live cattle (principally calves for fattening and unproductive animals) and 40,350,000 L of milk (principally to the companies Nestle, Pradel, and artisanal cheese makers; SIAP, 2008). Due to fluctuating and low milk prices, producers saw cheese making as an important alternative for providing value added to their milk. In this manner, cheese production has increased in the municipality of Tecpatan, also thanks to its high demand. Nevertheless, as with cattle production of other regions of Chiapas, lack of quality control of milk, cheese, and meat limits its sale in the formal market and causes prices to be significantly lower than expected.

Taking into consideration this situation, the objective of this study was to: i) carry out a socio-economic and technical characterization of traditional silvopastoral systems, and ii) evaluate the feasibility of converting traditional agrosilvopastoral systems of dairy cattle production to the organic model in three rural production societies (a type of cooperative) in a rural municipality in south-eastern Mexico.

2. Materials and methods

2.1. Location and characteristics of the study area

This study was carried out in southeastern Mexico, in the municipality of Tecpatan, in the mountains of the northeastern part of the State of Chiapas, between 93° 15′ and 93° 52′ West longitude and between 16° 59′ and 17° 23′ North latitude. The region is located in the mid-watershed of the Grijalva River, within the Mesoamerican Biological Corridor. Climate is warm humid with abundant summer rains Af (m) w" (i ') g. Total annual precipitation is 1932 mm, average altitude is 320 masl, and topography is rough. The current population is descended from the Zoque ethnic group.

2.2. Sampling and obtaining data

All cattle farms (CF: 75 = 100%) of three Rural Production Societies (RPS) were sampled: (i) RPS-Grijalva (RPS-G = 35CF) in the village of Luis Espinosa; (ii) RPS-Pomarroza (RPS-P = 22CF) in the village of Emiliano Zapata; and (iii) RPS-Malpaso (RPS-M = 18CF) in the village of Raudales Malpaso. Information was obtained through direct observations of the cattle farms and a questionnaire applied to producers using the semi-structured informal interview technique (Gillham, 2005). All information was obtained during the 2008 and 2009 agricultural cycles.

2.3. Methodology for characterization of livestock production systems

Characterization of the context of livestock raising and of the production process was carried out through use of some qualitative and quantitative structural and technical-economic indicators, previously defined by Toussaint (2002); Mena et al. (2004), and Nahed et al. (2006). Structural indicators included were: land tenancy, intergenerational continuity, producer's education level, training, technical assistance, manual labor used, type of access road to the farm, and access to running water and electricity, and producer age. Technical-economic indicators included were: land surface, grazing surface, agricultural surface, weedy surface, milking cows, animal load, milking time, milk produced, age at weaning, cows/breeding bull ratio, birth rate, calf and adult cattle death rates, net margin of income (average difference between brute margin − income minus operational expenses − and structural expenses, divided by average annual number of producing cows), and total beneficiaries in the family.

2.4. Evaluate approximation of conventional livestock production systems to the organic production model

By consulting twelve experts in organic livestock raising from different Spanish and Mexican institutions, and based on the organic regulations (CEU, 2007; IFOAM, 2009), we identified essential variables and indicators in order to design a simple methodological proposal which would allow for evaluating approximation of conventional livestock production units to the organic production model. For this, we used the OLPI methodology (Organic Livestock Proximity Index, applied to dairy goats), proposed by Mena et al. (2011). This methodology for evaluation was designed with 35 variables oriented toward constructing 10 indicators (Table 1) in order to integrate an organic livestock proximity index more suited to our purposes. The experts based their selection of variables and indicators on principles of the organic production model, which in turn is based on principles of ecological agriculture with respect to: i) use of permitted, prohibited, and restricted substances for preventing, curing, and eradicating illnesses, ii) use of agroecological technologies which are non-contaminating, less capital-dependent, do not degrade the environment, are based on efficient use of local resources, and allow for long-term maintenance of biological diversity and soil productive capacity (Guzman and Alonso, 2001); and iii) implementation of mechanisms for management and promotion of ecological livestock raising.

Table 1
Indicators, weighted factors, and variables which integrate the organic conversion index of conventional dual purpose cattle ranching in three rural production societies in Tecpatan, Chiapas, southeastern Mexico.

1) *Feed Management (0.12):*
1.1. Feeding animals only with feed permitted by the organic standards
1.2. Grazing
1.3. At least 60% of dry matter of the ration/day is common forage.
1.4. At least 50% of feed comes from the same or another ecological farm.

2) *Sustainable grassland management (0.15):*
2.1. Rotation of pastures
2.2. Appropriate stocking rate
2.3. Forage crop associations
2.4. Cultivation of woody forage (trees and/or shrubs)
2.5. Management of silvopastoral systems

3) *Soil fertilization (0.06):*
3.1. Chemical
3.2. Organic

4) *Weed control in grasslands and crops (0.06):*
4.1. Chemical
4.2. Organic

5) *Pest and disease control and grasslands and crops (0.06):*
5.1. Chemical
5.2. Organic

6) *Disease prevention and veterinary care (0.12):*
6.1. Application of vaccines only against endemic illnesses
6.2. Quarantining introduced and/or sick animals
6.3. Natural treatment of illnesses (herbalism, homeopathy, or nothing)
6.4. Natural internal and external deparasitation (herbalism, homeopathy, or nothing) and permitted allopathy

7) *Breeds and reproduction (0.06):*
7.1. Only Creole animals and/or those adapted to the region
7.2. Reproduction by direct mounting

8) *Animal welfare (0.07):*
8.1. Natural lactation until eight months of age
8.2. Sufficient space per animal in enclosed areas with roofs and in open air
8.3. Sufficient feeders and troughs
8.4. Protection from inclement weather in pastures (cold, heat, rain, humidity)
8.5. Cutting of horns (young animals) and trimming horns of animals of all ages

9) *Innocuity (0.15):*
9.1. Strict hygienic-sanitary control (of premises, equipment, and milking and milk management)
9.2. Animals have been demonstrated to be free of: (i) brucellosis and (ii) tuberculosis.
9.3. Animals seropositive to: (i) brucellosis and (ii) tuberculosis are eliminated.
9.4. Products have been demonstrated to be free of: (i) antibiotics, (ii) hormones, and (iii) pesticides.

10) *Ecological management (0.15):*
10.1. The producer receives technical support and/or training for organic certification.
10.2. The producer has an organic development plan or is certified.
10.3. The producer documents the organic process.
10.4. The producer receives stimulus for organic cattle production
10.5. The producer receives a fair and/or constant price for their products throughout the year.

2.4.1. Variables and calculation of indicator values

The 35 variables which comprise the 10 OLPI indicators were codified as binomial or dummy variables (0,1) in order to homogenize the different original units of measure and thus facilitate calculation of the value for each indicator. This procedure was due to the fact that that the organic regulations are based on well defined criteria or thresholds regarding use of permitted (1) and non-permitted (0) inputs and practices. The original data of some continuous variables, such as appropriate stocking rate (Table 1), were standardized as binomial, assigned a value of 1 when stocking rate was within the threshold (2 animal units/ha) permitted by the organic regulations, and a value of 0 when animal load was outside of the permitted threshold. In this manner, each variable acquired a unique, mutually exclusive value with a binomial or Bernoulli distribution (Zar, 1984), which simplified the method and facilitated calculation of the value for each indicator. The real value acquired by each indicator (without pondering) is the mathematical average of the values (or responses 0 or 1) of their own variables (Grimm and Wozniak, 1990). In this manner, the values for the ten indicators were standardized to a common or relative percentage scale (%). The optimal value (100%) of an unweighted indicator is achieved when the responses of all its variables are positive (codified as 1). Calculation of the percentage value for each indicator (I_j) was obtained through the sum of the responses of its variables (0 or 1) multiplied by 100. The equation used was:

$$I_j = \frac{\sum_{i=1}^{m} v_i}{m}(100)$$

Where:

$j = 1, 2, 3,......,10$ indicators
$i = 1, 2, 3,.....,m$ variables
v_i = variables for each indicator

2.4.2. Weighting of indicators

The weighted coefficient or specific weight of each indicator for the study region was defined by the twelve experts in function of : i) the importance of each indicator to agroecological principles and organic livestock raising; and ii) the difficulty in eliminating or substituting use of inputs or practices which are not permitted by the organic regulations (Table 1). The weighted coefficients which establish the hierarchy of the ten indicators in this study should not be taken as a generalized rule (Gallopin, 1997) due to the fact that these coefficients may vary from one region to another, depending on management conditions of the production systems. In order to apply the methodology in other regions, it is recommended that the weighted coefficients be adjusted in function of the particular management characteristics of livestock raising in each region. The weighted value of each indicator (PI_j) is obtained by multiplying the value of each indicator (I_j) by its specific weighted factor (PF_j). The equation used was:

$$PI_j = I_j(PF_j)$$

2.4.3. Organic Livestock Proximity Index (OLPI)

Construction of the Organic Livestock Proximity Index was based on the multi-criteria focus for weighting and aggregation of information (Munda et al., 1994; Falconi and Burbano, 2004; Munda, 2004). This index is a tool for: i) understanding in an integrated manner the technological and environmental limits and potentials of the livestock raising units in a particular economic and social context, and ii) operationalizing decision-making so that livestock raising units may transition toward organic production. The OLPI of each livestock farm was obtained through the sum of the pondered values for the ten indicators (PI_j), using the following equation:

$$\mathrm{OLPI} = \sum_{j=1}^{10} \mathrm{PI}_j$$

2.5. Systematization and analysis of information

Information was systematized respecting the actual grouping of the livestock raising production units studied in the three Rural Production Societies (RPS), previously pointed out in the section on sample design and obtaining information. The three groups of livestock raising units were characterized with quantitative and qualitative indicators. Average values for the quantitative indicators (technical-economic and those of OLPI) were examined through *one-way* analysis of variance in order to differentiate the groups, and those which proved to be different were later compared through the post hoc multiple comparison method of least significant difference (LSD). Qualitative (structural) indicators were examined through chi-squared independence tests among groups, through categorical data analysis in contingency tables (Zar, 1984). Statistical analyses were carried out with the 2006 Statistical Package for Social Sciences, version 15.0 (SPSS, 2006).

3. Results and discussion

3.1. Characterization and analysis of cattle raising in the study area

Historically, in the study region, the traditional agrosilvopastoral cattle production system has predominated, with the objective of producing milk and weaned calves for sale. This system is characterized by its low level of technological development, low use of external inputs, integral and diversified use of resources, and a management calendar adapted to the varied environmental conditions. Cattle raising is integrated with agricultural and forest production through energy flows and circulation of materials by fertilizing crops with manure, and by feeding cattle with agricultural residues and in pasture units with a tree gradient ranging from extensive grasslands (without trees) to grasslands with living fences, shrubs and/or fallows, dispersed trees, and forested areas, used in a rotating manner over the course of the annual cycle.

Producers of the three Rural Production Societies have an average age of 46 ($\pm$1.9). These producers have shown greater openness to guidance and training, and greater interest in technological innovations than older adults. This provides an opportunity for development of agrosilvopastoral systems and organic cattle raising. Table 2 shows that a high proportion of producers believe that one of their children or another family member will continue to raise cattle. All three RPS include cattle farms within "ejidos" (a form of collective landholding) and private tenancy (Table 2). Nevertheless, in the RPS Grijalva and Pomarroza, ejido property predominates and in Malpaso, private property predominates. The majority of producers have completed secondary education, a minority are illiterate, and another minority have high school or technical education. Such a situation of greater openness of younger adult producers with a similar level of education has been reported by Nahed et al. (2010) for ejido cattle raising in the community Tierra Nueva in the "El Ocote" Biosphere Reserve in Chiapas.

Table 2
Structural indicators for cattle farms for three rural production societies in Tecpatan, Chiapas, southeastern Mexico.

Indicator	Group of milk producers		
	RPS-Grijalva	RPS-Pomarroza	RPS-Malpaso
$N = (75)$	35	22	18
Land tenancy[a], %*			
Ejidal[c]	62.9	77.3	5.6
Private property	37.1	22.7	94.4
Intergenerational continuity, %**	77.1	86.4	77.8
Level of formal education[b], %**			
Illiterate	11.4	13.6	16.7
Primary education	54.3	72.7	33.3
Middle school	20.0	13.6	16.7
High school	11.4	0.0	16.7
University	2.9	0.0	16.7
Training[b], % **	28.6	23.3	33.3
Technical assistance[b], %**	25.7	27.3	11.1
Credit support[b], %**	31.4	22.7	22.2
Manual labor[a], %**			
Family	100	100	100
Hired permanent	34.3	40.9	44.4
Hired occasional	54.3	31.8	38.9
Hired occasional a nd permanent	11.4	27.3	16.7
Access road[a], %**			
Good condition	28.6	50.0	38.9
Bad condition	71.4	50.0	61.1
Running water[a],%**	37.1	22.7	22.2
Electricity[a], %*	31.4	22.7	72.2

*X^2_{RV} significant differences among groups of milk producers ($p < 0.05$); ** Non-significant differences among groups of milk producers ($p > 0.05$).
[a] % of cattle farms.
[b] % of producers.
[c] Form of collective landholding.

While producers are organized in cattle raising associations and rural production societies, few receive training, technical assistance, and credit (Table 2). Most work on all the cattle farms is carried out by family members. Nevertheless, a large percentage of producers contract permanent and/or temporary workers. Few cattle farms of the three rural production societies have an access road in good condition, running water, or electricity. This greatly limits implementation of innovations, improvement of premises and equipment, and general development of production systems (Nahed et al., 2011).

All cattle farms have Zebu and Creole cattle crossed with European breeds, principally Swiss, Holstein, and – to a lesser extent – Simmental. In the majority of the farms, cows are milked manually once a day (97%) using the technique known as traditional "rejeguería", which consists of stimulating milk flow by feeding the calves for 2–3 min before beginning to milk. This milking technique is well adapted to the Mexican tropics and has been described by Ortiz (1982).

Table 3 shows the technical-economic variables of the cattle farms which were evaluated. With the exception of the variables "milk produced per cow per day during the dry season" and "number of cows per bull", variables did not significantly differ ($p > 0.05$) according to the rural production society to which the cattle farms belong. The cattle farms of the Malpaso Rural Production Society show the favorable tendencies ($p > 0.05$) of greater total pasture area, greater number of milking cows, and higher birth rate. Nevertheless, this rural production society shows the disadvantage of having poorer disease control, as reflected in the greater ($p > 0.05$) death rate of calves and adult cattle. The Malpaso

Table 3
Technical-economic indicators for cattle farms for three rural production societies in Tecpatan, Chiapas, southeastern Mexico.

Indicator	Group of milk producers			$F_{(df1/df2)}$; *p*-values
	RPS-Grijalva	RPS-Pomarrosa	RPS-Malpaso	
N = (75)	35	22	18	
Total land surface, ha	33.9 (±5.2)	38.8 (±5.1)	48.8 (±5.2)	NSD
Grazing surface, ha	29.2 (±0.4.8)	29.5 (±5.2)	41.9 (±5.6)	NSD
Agricultural surface, ha	2.7 (±1.3)	5.4 (±1.9)	4.8 (±1.7)	NSD
Weedy surface, ha	1.9 (±0.8)	3.9 (±1.1)	2.1 (±0.6)	NSD
Milking cows, no.	21.1 (±2.0)	16.6 (±2.2)	22.8 (±2.9)	NSD
Animal load, UA/ha	2.3 (±0.4)	2.4 (±0.8)	1.8 (±0.4)	NSD
Milking time, number of months	9.7 (±2.3)	7.7 (±0.2)	8.9 (±1.6)	NSD
Milk produced/cow during dry season, l	4.1 (±0.1)^{ab}	4.3 (±0.1)^{a}	3.8 (±0.1)^{b}	4.8 (2/72); 0.011
Milk produced/cow during rainy season, l	5.1 (±0.2)	4.9 (±0.1)	5.1 (±0.3)	NSD
Milk produced/cow and year, l	1190 (±101.0)^{b}	962 (±27.5)^{b}	1576(±90.4)^{a}	9.0 (2/72); 0.0001
Age upon weaning, months	7.7 (±0.1)	8.1 (±0.2)	7.8 (±0.2)	NSD
No. cows/breeding bull	22.3 (±0.4)^{b}	21.6 (±0.5)^{b}	23.7 (±0.5)^{a}	4.5 (2/72); 0.013
Birth rate, %	72.0 (±1.5)	72.7 (±1.6)	73.6 (±1.8)	NSD
Calf death rate, %	5.3 (±1.9)	5.0 (±2.2)	7.3 (±2.4)	NSD
Death rate adults, %	2.6 (±)	4.0 (±)	5.1 (±)	NSD
Net margin/cow per year, €	232.6 (±24.0)	236.8 (±187)	270.8 (±17.8)	NSD
Total beneficiaries in family, N°	4.5 (±0.3)	4.0 (±0.4)	5.0 (±0.5)	NSD
*Producer age, years	48.3 (±1.6)	42.4 (±1.7)	47.5 (±2.3)	NSD

a,b = significant differences among groups of milk producers ($p < 0.05$); NSD = Non significant difference; df = Degrees of Freedom; RPS = Rural Production Societies (Rural Cooperatives).
*For practical reasons, this structural indicator is included in this table since is it also a quantitative indicator.

Rural Production Society has the greatest net profit margin per cow per year and greater number of beneficiaries in the family. The stocking rate observed on the cattle farms of this rural production society is within the margin permitted by the organic regulations, while animal load of the rural production societies Grijalva and Pomarroza surpass the two animal units per hectare permitted by the organic regulations (IFOAM, 2005).

In all cattle farms, the bull remains with the cows at all times, and breeding occurs through direct mounting. Therefore, calves are born throughout the year and weaning is not controlled. Most producers sell their milk to the companies Pradel (97.3) and Nestle (1.3%), and to artisanal cheese makers (1.3%). All male calves are sold upon weaning in order to be fattened in other regions of Mexico. Sale of milk, weaned calves, and unproductive cows are the principal sources of income for producers and serious problems exist with intermediaries in marketing, as occurs in many regions of tropical Mexico (Ortiz, 1982) and other regions of the world (Niemeyer and Lombard, 2003; Garcia et al., 2007).

3.2. Organic conversion index for cattle farms grouped by rural production society

Table 4 shows average percentages of approximation to the organic model for the ten indicators, as well as the multi-criteria organic conversion index of the cattle farms, grouped by rural production society. Rural production societies do not significantly differ ($p > 0.05$) in any of the ten indicators, nor in the organic conversion index. In general, the cattle farms of the three rural production societies have a favorable organic conversion index, and indicators for feed management and breed and reproduction comply with the organic regulations in a satisfactory manner. Indicators for sustainable grassland management, organic soil fertilization, weed control, pest and disease control, and animal welfare approximate the organic standards favorably to very favorably (57.0–90.0%), while approximations for disease prevention and veterinary care, innocuity, and ecological management are not very favorable (28.0–50.0%).

3.2.1. The first indicator, feed management (Table 4), shows that the cattle farms of the three rural production societies fully comply with the organic regulations

This is due to the fact that cattle are exclusively fed by: i) grazing, which means that the farm totally complies with the requisite that ii) at least 60% of dry matter of the daily ration is common forage, green (grazed or cut), dehydrated, or silaged, and that iii) at least 50% of feed comes from the same or another organic farm. Use of external feed supplements is absent, with the exception of a few farms which sporadically provide non-ecological commercial mineral salts to the animals. The most important strength of the cattle farms in the three rural production societies evaluated is animal feeding based on grazing and lack of use of prohibited feed such as animal excrement, commercial feed, and chemical additives (IFOAM, 2005; CEU, 2007; Müller-Lindenlauf et al., 2010). Nevertheless, some farms need to substitute the use

Table 4
Indicators and index of approximation to the organic production model (%) for cattle farms for three rural production societies in Tecpatan, Chiapas, southeastern Mexico.

Indicator	Group of milk producers		
	RPS-Grijalva	RPS-Pomarrosa	RPS-Malpaso
N = (75)	35	22	18
1.Feed management	100 (±0.0)	100 (±0.0)	100 (±0.0)
2.Sustainable grassland management	60.0 (±2.5)	57.9 (±3.8)	61.1 (±3.6)
3.Soil fertilization	80.0 (±6.9)	86.4 (±7.5)	88.9 (±7.6)
4.Weed control in grasslands and crops	77.1 (±7.2)	86.4 (±7.5)	66.7 (±11.4)
5.Pest and disease control in grasslands and crops	60.0 (±8.4)	86.4 (±7.5)	72.2 (±10.9)
6.Disease prevention and veterinary care	28.6 (±2.1)	30.7 (±2.9)	32.0 (±2.8)
7.Breeds and reproduction	100 (±0.0)	100 (±0.0)	100 (±0.0)
8.Animal welfare	80.0 (±0.0)	80.0 (±0.0)	80.0 (±0.0)
9.Innocuity	50.0 (±0.0)	50.0 (±0.0)	50.0 (±0.0)
10.Ecological management	40.0 (±0.0)	40.0 (±0.0)	40.0 (±0.0)
Organic conversion index	62.2 (±0.92)	64.6 (±1.1)	63.4 (±1.2)

RPS = Rural Production Societies (Rural Cooperatives).

of non ecological mineral salts for other salts which the organic standards permit.

3.2.2. For the second indicator, sustainable grassland management, the three RPS have a favorable approximation to the organic model (close to 60%)

This is due to variation in use of techniques such as: i) rotation of grasslands (RPS-G = 94%; RPS-P = 82%; RPS-M = 100%), ii) an average stocking rate of 1.8 (±1.5) animal units/ha of grassland (the three RPS comply 100% with the organic regulations), iii) forage crop associations (8% in the three RPS), iv) cultivation of woody forage plants RPS-G = 17%; RPS-P = 0.0%; RPS-M = 6%), and v) management of silvopastoral systems (RPS-G = 29%; RPS-P = 50%; RPS-M = 39%). In order to achieve sustainable grassland management, it is necessary to favor associations of leguminous species in grasslands which are currently gramineae monocultures, as well as plant local woody forage species such as *Guazuma ulmifolia*, *Leucaena* sp, *Gliricidia sepium*, *Erithryna* sp, and *Brosimum alicastrum* in agronomic arrangements. In this way, diversified grasslands offer greater soil protection, favor biodiversity, and provide environmental services such as carbon capture, reduction in emissions of CH_4 and nitrous oxide, and mitigation of global warming (Pimentel et al., 2005; Müller-Lindenlauf et al., 2010).

3.2.3. With respect to the third indicator, soil fertilization, all cattle farms had favorable approximations to the organic production model (RPS-G = 80%; RPS-P = 86%; RPS-M = 88%)

Although this indicator refers to a variety of forms of organic fertilization, in the three rural production societies grasslands are almost exclusively fertilized with manure which the animals naturally deposited while grazing. On some cattle farms, chemical fertilizers were sporadically used, resulting in mixed fertilization (organic and chemical). The few cattle farms which currently use chemical fertilizers should substitute them with organic fertilization techniques and manure management systems (Lague et al., 2005; Pimentel et al., 2005).

3.2.4. For the fourth indicator, weed control in grasses and crops, RPS-P has the highest approximation (86%) to the organic standards, followed by RPS-G (77.1%) and RPS-M (66.6%)

In general, producers of the three rural production societies control weeds manually (60.0%), mechanically (9.3%), and chemically (17.3%), and some do not carry out any weed control (10.6%). Effective ecological weed control consists of maintaining populations of weed species which grow spontaneously in grasslands and crops at acceptable levels, preventing excessive multiplication without eradicating them completely (Menalled et al., 2001).

3.2.5. For the fifth indicator, ecological control of pests in grasses and crops, RPS-G complies 60% with the organic regulations, RPS-P = 86%, and RPS-M = 72%

In general, 70.7% of producers do not carry out any pest control, 1.3% use biological pesticides, and 28% use chemical pesticide. The most frequent insect pests are Falso Medidor (*Trichoplusia ni*), Mosca Pinta (*Aeneolamia* spp.) and Gallina Ciega (genus *Phyllophaga*). Use of botanical insecticides and repellents (Isman, 2006), and integrated pest management which includes ecological soil and biodiversity management techniques (Cook et al., 2007), are methods for reducing pesticide use.

3.2.6. For the sixth indicator, disease prevention and veterinary care, the three rural production societies show an unfavorable approximation to the organic model

This is due to varying levels of use of permitted techniques such as: i) vaccination against endemic diseases (RPS-G = 17.1%; RPS-P = 13.6%; RPS-M = 16.6% such as Derriengue, Clostridiasis, and Pasteurelosis), ii) quarantining introduced or sick animals (RPS-G = 18.2%; RPS-P = 19.5%; RPS-M = 18.9%), iii) natural treatment of infectious diseases (RPS-G = 94.2%; RPS-P = 100%; RPS-M = 100%); and iv) natural treatment of internal parasitosis (RPS-G = 2.8%; RPS-P = 9.0%; RPS-M = 11.1%) and external parasitosis (0.0% in the three RPS). Some producers do not carry out any internal deparasitation and others carry out more than the two per year permitted by the organic regulations. The majority of producers sporadically use antibiotics to treat their animals. Preventive measures which would help to improve this indicator are those which promote adaptation to the environment and resistance to illness, adequate nutritional management, raising of Creole animals and their crosses, as well as replacing chemical medications (such as antibiotics and anti-parasite medicines) with natural methods such as homeopathy and herbalism (IFOAM, 2005; CEU, 2007).

3.2.7. For the seventh indicator, animal breeds and reproduction, the CF of the three rural production societies comply 100% with the organic regulations

This means that the farms only raise Creole cattle and/or others which are adapted to the region, and animal reproduction is natural. The adaptation of the animals to local climatic and management conditions is reflected in the acceptable birth rate 68.0% (±25.6); cow/breeding bull ratio 22.4% (±2.3); calf death rate 7.4% (±2.2), and adult cattle death rate 4.3% (±1.8). Although the organic standards permit artificial insemination, in 100% of the farms, breeding is natural (direct) and continual, as are estrus and births, and chemically synthesized hormones are thus avoided. The organic standards stipulate that farms should have Creole animals and/or crossed breeds adapted to the region. This is the basis of organic livestock production, which promotes adaptation of the animals to specific regional conditions and development of resistance to illnesses and to predominant parasites (IFOAM, 2005; CEU, 2007; Rozzi et al., 2007).

3.2.8. For the eighth indicator, animal welfare, the cattle farms of the three rural production societies are very closely approximated (80%) to the organic standards

This is due to the fact that the cattle farms comply 100% with the following stipulations: i) natural lactation of calves until eight months of age, ii) sufficient space per animal in enclosed areas with roofs, iii) sufficient feeders and troughs, and iv) the animals' horns are cut or trimmed at all ages. Nevertheless, v) protection from inclement weather (cold, heat, rain, humidity) is deficient or absent in the three rural production societies. In organic livestock raising, animals should be offered optimal conditions for developing their reproductive and productive functions and satisfying their biological needs (von Borell and Sorensen, 2004).

3.2.9. For the ninth indicator, innocuity, the cattle farms of the three rural production societies are not very closely approximated (50%) to the organic model

In 100% of the cattle farms of the three rural production societies, the cattle have been demonstrated to be free of brucellosis (plate agglutination test) and tuberculosis (bovine tuberculin test), and the few animals which are seropositive to these illnesses are eliminated. On the other hand, in 100% of the cattle farms of the three rural production societies, there is a lack of strict hygienic-sanitary control of the premises and equipment and of milking and milk management. Until now, the products (milk, meat, and cheese) have not been demonstrated to be free of antibiotics, hormones, pesticides, and other chemical substances. Demonstration of innocuity of animal products (milk, meat, and cheese) is the producer's guarantee of quality to the consumer. Lack of compliance with this indicator among the traditional agro-silvopastoral systems evaluated greatly reduces compliance with the organic regulations. In order to improve this aspect, it is necessary to implement strict hygienic-sanitary control of the premises, equipment, and utensils, and of management of milking and milk, avoiding the use of chemical substances (such as pesticides, antibiotics, and detergents); eliminating biological vectors (viruses, bacteria, fungus, parasites), and preventing physical hazards (pieces of metal, splinters, manure, and garbage). These characteristics, together with sensory traits (taste, smell, and color of the milk, meat, and cheese) and nutritional factors constitute sanitary and nutritional quality of the food and lead to a high level of consumer confidence (Vaarst et al., 2005).

3.2.10. For the tenth indicator, ecological management (Table 4), the cattle farms of the three rural production societies are unfavorably approximated (40%) to the organic standards

In 100% of the cattle farms of the three rural production societies, producers: i) receive intermittent technical support and or training for organic certification and ii) have an organic development plan or are certified. Nevertheless, 100% of the cattle farms evaluated: iii) do not keep internal records of the organic process, iv) do not receive stimulus for production in transition to organics, and v) do not receive a fair and/or constant sale price for their products throughout the year. Of the traditional agro-silvopastoral systems evaluated in the three rural production societies, ecological management was one of the indicators with the lowest levels of approximation to the organic model. It is necessary to delineate procedures which producers should follow in order to obtain permanent technical support and training to initiate organic certification of their farms. There is a need for internal control of production, processing, and marketing according to the organic standards (CERTIMEX, 2009). Management should include negotiation and incentives to stimulate producers to generate better quality products. This includes fair and constant prices throughout the year for their products in order to stimulate producers to continue to increase their use of appropriate sustainable production and management techniques (Niemeyer and Lombard, 2003; von Borell and Sorensen, 2004; Nahed et al., 2006).

3.3. Use of indicators to evaluate conversion of conventional cattle raising systems to organics

In the face of increasing demand for organic animal products and consumer demand for innocuity of these foods, producers should guarantee quality of their products through clear and precise indicators for certification and credibility. For this to be carried out, it is necessary to document methods of evaluation of agricultural systems and laboratory analysis techniques which guarantee authenticity of organic milk and other animal products (Kouba, 2003).

Previous studies report those indicators which have been used to analyze farm sustainability (Coffey et al., 2004; Nahed et al., 2006; Galan et al., 2007; Peacock and Sherman, 2010), animal welfare (Napolitano et al., 2009; Phythian et al., 2011), environmental effects, effects of animal welfare on quality of milk on organic farms (Müller-Lindenlauf et al., 2010), and differences between organic and conventional farms (Nauta et al., 2006; Rozzi et al., 2007). Other studies evaluate the technical and economic performance of organic farming (Benoit and Laignel, 2009; Benoit and Laignel, 2009). Nevertheless, literature on conversion to organic farming is sparse (Lamine and Bellon, 2009), and few specific methods have been proposed for evaluating the possibilities of such conversion (Olivares et al., 2005).

In our case study, upon adapting the Organic Livestock Proximity Index (OLPI) methodology proposed by Mena et al. (2011), the following changes were made to the original methodology in order to suit our purposes: i) the original OLPI which has nine indicators was modified to ten indicators due to the fact that the original OLPI combines weed control in grasslands and crops and pest and disease control in grasslands and crops into one indicator, and the modified OLPI separates them into two indicators; ii) the original OLPI includes 56 variables, and the modified OLPI 35 variables; iii) the original OLPI was applied to goat raising systems in southern Spain, and the modified OLPI was successfully applied to cattle raising systems in southeast Mexico; iv) some of the original OLPI's weighting coefficients of the indicators were modified, adjusting them according to the management conditions of the livestock production systems studied; v) equations of the original OLPI were slightly modified as a function of changes in number of indicators, number of variables, and the weighting coefficients.

As a result of these changes, we found that the OLPI values of the cattle raising units evaluated in the three RPS are greater than those of conventional cattle raising of the Frailesca Region (48.0 $\pm$ 0.7; Aguilar-Jimenez, 2011) and the Municipality of Marques de Comillas (53.3 $\pm$ 0.9; Nahed et al., 2009) in the state of Chiapas, Mexico. This is due to the fact that the livestock raising units of the three RPS show: i) higher values of approximation to the organic production model for the indicators feed management, ecological pest and disease control, and ecological management; and ii) similar values for indicators of sustainable grassland management, breed and reproduction, animal welfare, veterinary prevention and care, and innocuity compared to those of conventional cattle raising of the Frailesca and Marques de Comillas regions.

Other comparative studies which use different methodologies report the following results. Rozzi et al. (2007): i) compared to conventional farms, organic farms had lower milk production, a lower replacement rate, a higher somatic cell count, and a much higher rate of crossbreeding; ii) culling rate for organic farms was 21%, and principal reasons for discarding animals were infertility, mastitis, problems with feet and legs, reduced production, and old age; and iii) principal areas of concern expressed by organic dairy farmers were related to grazing, fertility, health, and longevity. Hörning (1998) concluded that ecological systems achieve greater animal welfare than conventional systems. Sundrum (2001) concluded that no significant differences were found upon comparing indicators for animal health in conventional and organic systems. Meanwhile, Ebbesvik and Loes (1994) report a decrease in metabolic illnesses in organic livestock systems. In general, attention to animal health in organic livestock systems is as good or better than in conventional systems (Lund, 2006). Nevertheless, organic livestock raising is criticized due to the fact that animals are frequently underfed and infected with parasites due to restrictions in use of anthelmintics (Vaarst et al., 2005). In organic livestock raising, preventative management requires application of biological knowledge rather than depending on allopathic medicines, and uses information regarding epidemiology, immunity, nutrition, appropriate housing design, animal behavior, and farmer care of the animals.

Field studies have emphasized the negative effects of pesticide use on plant diversity, while leaving the edges of the field unsprayed considerably enhances diversity of plant species; and fertilizer use negatively affects biological diversity of vegetation on the edges of fields (Guivant, 2003). Thus, based on the literature, observed differences in plant diversity between organic and conventional fields may be attributed to herbicide use of conventional livestock raising, although other farming practices such as chemical fertilization may also be partially responsible (Petersen et al., 2006).

In a literature review, de Boer (2003) reports an acidification potential of milk production of 78–97% due to volatilization of ammonia, which is not necessarily reduced when switching from conventional to organic milk production. The eutrophication potential per ton of milk or per hectare of farmland was lower for organic than for conventional milk production due to lower fertilizer (whether organic or chemical) application rates in organic production. The potential contribution of conventional milk production to global warming is 48–65% due to methane emissions. Organic milk production inherently increases methane emissions; therefore its contribution to global warming may only be reduced by considerably reducing carbon dioxide and nitrous oxide emissions.

Kouba (2003) points out that several comparative evaluations of conventional and organic systems do not show consistent differences in nutritional quality of milk, while conventional animal products have greater residual levels of veterinary medicines and pesticides. Meanwhile, Sundrum (2001) did not find differences in bacteria count between organic and conventional milk.

These comparisons allow for demonstrating multi-criteria limits and potentials of organic livestock raising and help to identify where research and development efforts should be directed in order to advance in converting conventional livestock raising systems to organics.

3.4. Limits to and feasibility of converting to organic cattle raising in our case study

It is important to evaluate the level of approximation of current traditional agrosilvopastoral systems to the organic production model in order to identify structural and functional (management) limits and potential to stimulate organic production (Niemeyer and Lombard, 2003; Pimentel et al., 2005; Nahed et al., 2006). Thus, the multi-criteria organic conversion index values for the three rural production societies evaluated are favorable despite the fact that producers need to improve sustainable grassland management, disease prevention and veterinary care, innocuity, and ecological management. This is principally due to the fact that the great majority of cattle farms do not use agrochemicals, but rather traditional and/or agroecological methods. The cattle farms evaluated in the three rural production societies have an intermediate level of compliance with the organic regulations (55–75%).

In general, the level of compliance with the organic model of the traditional agrosilvopastoral systems evaluated in this study is more due to traditional management with low use of external inputs than to use of sustainable production technologies and ecological management. Reversing the current scenario toward the desirable ecological production scenario according to the rigorous organic standards means waiting for the necessary transition or conversion period in order to reduce to a minimum the residual effect of the current sporadic use of agrochemicals, as well as the effects of those previously used. It is also necessary to teach producers how to substitute contaminating technologies dependent on capital and those which degrade the environment with others which require less capital and which are based on efficient use of local resources, thus maintaining biodiversity and long term productive capacity of the soil (Pimentel et al., 2005). The list of permitted, prohibited, and restricted substances indicated by the organic standards should be reviewed and respected. Finally mechanisms for management of organic cattle raising should be promoted.

According to the International Federation of Organic Agriculture Movements (IFOAM, 2005), the transition period varies from 12 to 48 months depending on previous management and the rigor of the certifier. Based on the OLPI values, traditional agrosilvopastoral systems of the three rural production societies should improve their indicators for sustainable grassland management, veterinary care and prevention, innocuity, and ecological management. RPS-Grijalva should also strengthen the indicator for pest and disease control in grasslands and crops, and RPS-Malpaso should improve the indicator for weed control in grasslands and crops. So that the livestock raising units may transition toward the organic production model, the period of transition toward organic production of all the livestock raising units evaluated is expected to be less than 24 months, due to the fact that these cattle systems use traditional management techniques. Conversion would simultaneously affect the entire production unit, including animals, pasture areas, and any plot used for animal feeding (CERTIMEX, 2009).

The importance of producing high quality animal products principally lies in their positive effect on the health of those who consume them, as consumers are becoming increasingly more demanding of the innocuity and environmental friendliness of their food (Hermansen, 2003). Certification of foods of animal origin with these characteristics offer new options in the current market dynamic, since, due to their quality, they may compete with foods produced conventionally in extensive or intensive systems (Niemeyer and Lombard, 2003). Therefore they constitute a positive option for building well-structured chains of value (Lundy et al., 2004; Midmore et al., 2001).

4. Conclusions

The level of approximation of the traditional agrosilvopastoral systems studied to the organic production model obeys traditional management with low use of external inputs more than use of sustainable organic production technologies.

Producers of the three rural production societies must improve their farms with respect to the ten indicators evaluated, especially sustainable grassland management, ecological weed control, pests and diseases in grasses and crops, veterinary prevention and medical care, innocuity, and ecological management.

In order to achieve these improvements, it is necessary to take advantage of the opportunity of the level of approximation to the organic model of the traditional agrosilvopastoral systems evaluated, whose potential lies in low use of external inputs, use of traditional technology, and artisanal characteristics of the animal products. Also, financial and technical support, training, organization, and management of production, transformation, and marketing should be strengthened. Furthermore, a policy of development of organic cattle raising should be put into place – especially a policy of agro-alimentary sanitary quality which considers costs of organic certification and promotion of products in national and international markets. In this manner, milk, meat, and cheese from the three rural production societies evaluated could be certified as organic or of maximum quality in order to be marketed nationally and internationally, thus benefiting producers and consumers.

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