



# Integrating links between tree coverage and cattle welfare in silvopastoral systems evaluation

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## Abstract

Livestock production in Latin America is strongly associated with deforestation. Silvopastoral systems are an alternative; however, the relation between animal welfare and tree coverage has been poorly studied. We hypothesized that a connection between these features exist and that its evaluation can influence system management decisions. A general assessment of tree coverage percentage and tree distribution in ten Mexican cattle ranches was performed using satellite images. Animal welfare indicators from the Welfare Quality® dairy cattle protocol measurable in extensive conditions were also assessed. Tree coverage percentage was highly variable and formed a gradient (52.42% in Ranch J2 to 2.00% in Ranch S1). The tree coverage percentage of two ranches was deemed as silvopastoral (between 22 and 35%). Body condition was better in ranches with high tree coverage compared to those with low ( $P < 0.05$ ). The percentage of wooded grassland was negatively correlated with flight distance reductions ( $P < 0.05$ ). Less integument alterations were present in high tree coverage ranches compared to low ( $P < 0.05$ ). Our landscape analysis showed the presence of different vegetal compositions in silvopastoral systems of the Mexican tropics. This knowledge can be applied to improve management decisions and promote the use of silvopastoral systems in the area. Additionally, this is the first study proving a relationship between landscape structure and welfare indicators, since body condition and integument alterations were positively affected. Although our results need further research, similar analyses can be implemented to improve cattle well-being in production systems associated to trees. In conclusion, landscape analysis in combination with animal welfare measurements could increase productivity by identifying important links between cattle welfare and the presence of trees, as well as help to identify areas of further research for the implementation of silvopastoral systems in Mexico.

**Keywords** Animal welfare · Dairy cattle · Flight distance · Silvopastoral systems · Sustainability · Welfare quality

## 1 Introduction

Livestock production is one of the most important anthropogenic drivers of environmental change, as it is associated with

deforestation, loss of biodiversity, and reduction of ecosystem services (Van Oudenhoven et al. 2012). Due to its continuing growth, forest areas worldwide have been reduced by 129 million hectares between 1990 and 2015 and are now less than 4 billion hectares (FAO 2016). Furthermore, rapid growth in global population and per-capita consumption are set to increase the problem ((FAO 2013).

In Latin America, livestock production corresponded to 27.1% of the total land area in 2009 (FAO 2009) and as it mainly takes place in extensive tree-cleared areas, it accounts for almost 70% of deforestation (FAO 2016), which in turn has generated the loss of carbon storage, decreased water availability, and an increase in soil nutrients (Balvanera et al. 2009; Challenger et al. 1998; De Haan et al. 1997). In Mexico, it has also proven to be highly inefficient as is related to inappropriate technology, health problems in cattle, and low economic benefits for communities (Murgueitio et al. 2011;

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Steinfeld et al. 2006; Améndola et al. 2016). As a consequence, there is a great interest in transforming conventional grazing systems based on monoculture of grass to more structurally complex systems, such as silvopastoral systems (SPSs), which are associations of pasture land with trees or shrubs potentially beneficial for both food production and the provision of environmental services (Bautista Tolentino 2009; Broom et al. 2013).

Tree coverage distribution and heterogeneity are characteristics of SPSs that can relate to the quality and quantity of environmental services (Betancourt et al. 2003; Ibrahim et al. 2011; Montagnini 2009; Sáenz et al. 2006). It has been suggested that tree coverage percentages ranging between 22 and 35% can generate the ideal combination for both environmental and production benefits, as biodiversity levels and pasture consumption rates by cattle are enhanced (Blackshaw and Blackshaw 1994; Esquivel 2007; Ibrahim et al. 2004; Pezo and Ibrahim 1998; Topps 1992). Tree coverage in agricultural landscapes have different distributions such as forest fragments, riparian forest, grasslands with live fences, and wooded grasslands (Ibrahim et al. 1999; Murgueitio 2005; Harvey et al. 2006; Harvey and Sáenz 2008). Each type of distribution is associated with different productive and environmental benefits; therefore, spatial heterogeneity (the presence of several types of distribution in a given area) is also considered an important feature of the SPSs (Daily et al. 2001; Estrada et al. 1998; Harvey et al. 2006; Petit and Petit 2003).

In addition to the analysis of tree coverage features, an integral analysis of tree cover transformation within extensive livestock systems should consider the welfare of cattle in relation with the new environments. Animal welfare refers to the state of an individual in relation to its ability to cope with its environment (Broom 1991). While cattle welfare problems in extensive systems, such as heat stress in absence of shade, are well known (Hahn 1999; Pagot 1992; Pires et al. 2008), there is evidence indicating that cattle benefit from browsing certain leguminous trees and shrubs as they increase their body condition, which impacts their overall health, welfare, and productivity (Aguilar and Condit 2001; Castañeda Nieto et al. 2003; Esquivel 2007; Ku Vera 2005; Solorio-Sánchez et al. 2000); there is no information on the benefits of different levels of tree coverage in SPSs on animal welfare indicators. This information could be used to set criteria for designing SPSs that provide appropriate trade-offs between ecosystem services, production yield, and animal welfare.

In this study, we describe the tree cover structure of ten tropical ranches in the central portion of Veracruz, Mexico, as a proxy to better describe the nature and orientation of production systems. Additionally, we evaluated some welfare measures from the cattle at these ranches and scored them according the Welfare Quality® protocol (WQ 2009). We conducted an exploratory analysis to identify potential links between these measures and the existent landscape features we explored. This information is

useful to identify research priorities and areas of opportunity for the generation of multidimensional evaluation protocols for livestock systems that contemplate the economic, social, environmental, and animal health aspects of a given system.

## 2 Methods and materials

### 2.1 Study area

Ten cattle ranches located in central Veracruz, Mexico, were selected for this study. These are located in the municipalities of Cotaxtla (C; Ranches La Capilla [C1] and La Candelaria [C2]), Medellín (M; Ranches El Rubí [M1] and Casablanca [M2]), Veracruz (V; Ranches La Parroquia [V1] and Torreón del Molino [V2]), Jamapa (J; Ranches La Reforma [J1] and El Copite [J2]), and Soledad de Doblado (S; Ranches Los Laureles [S1] and Piedra del Indio [S2]). The ranches were selected taking into account the willingness of owners to participate in this study, the accessibility to the property, and the presence of dual-purpose herd (i.e., beef and milk production) while trying to maximize the variation on vegetation cover. Each ranch was visited once during the months of October to December 2009 (early dry season) for data collection. According with the National system of Meteorology of Mexico (<http://smn.cna.gob.mx>), the average temperature and precipitation in the municipalities where the ranches were located during these months in 2009 was Cotaxtla  $24.2 \pm 1.1$  °C,  $47.4 \pm 25.2$  mm; Medellín  $23.6 \pm 0.9$  °C,  $66.2 \pm 36.4$  mm; Veracruz  $25.03 \pm 0.9$  °C,  $142.2 \pm 41.4$  mm; Jamapa  $24.6 \pm 1.6$  °C,  $39.2 \pm 16.5$  mm; Soledad del Doblado  $23.8 \pm 1.03$  °C,  $29.3 \pm 13.4$  mm).

### 2.2 Animals

Ten Zebu/European crossbred dual-purpose herds (average age 36–120 months old), with an average of 90 cows each, were assessed. In all cases, the herds were kept grazing all year round with supplementation with mineral salts, silage, urea (2%), or cut forage. On average, animals produced 536.974 kg of milk and 78, 200 kg of meat annually. The average stock density for these ranches was 1.3–1.5 individuals/ha.

### 2.3 Vegetation analysis

In each ranch, two global positioning system (GPS) (Garmin model eTrex Legend HCx, USA) readings were used to obtain decimal coordinates of the grazing paddocks perimeter for global positioning. This information was stored and downloaded to a computer using the software Trip & Waypoint Manager (Garmin, USA). Using these coordinates, QuickBird satellite images at 1 km height were obtained (Fig. 1). These images were sourced from captions from March 15, June 13, or November 17, 2007. After satellite

**Fig. 1** Satellite image of Ranch J2, El Copite **a** before georeferencing and **b** georeferenced with the program ArcGis 2.3. The black line represents the limits of the ranch area while the pink shading indicates the tree coverage within the ranch



images were obtained, they were georeferenced using the software ArcView GIS version 3.2 of the ArcGIS package. The area coordinates given in decimal degrees were transformed to the Universal Transverse Mercator (UTM) Coordinate System.

According to the noticeable characteristics of the plant elements in the satellite images, such as color, pixel density, and visible canopy shade, two main components of vegetation were defined: (1) tree coverage and (2) grassland coverage. Tree coverage was composed of plants with woody elements  $\geq 4$  m high and included different landscapes in the paddocks such as (a) live fences: linear tree elements dividing spaces within or outside the polygon defined as the grazing paddock; (b) riparian forest: linear tree items associated with the margins of rivers or streams; (c) forest fragments: irregular areas composed of trees with their crowns in contact and forming closed elements with areas  $\geq 1.500$  m<sup>2</sup>, and (d) wooded grassland: pasture areas of herbaceous vegetation combined with trees distributed in a relatively homogeneous manner (either

individually or in closed fragments  $\leq 1500$  m<sup>2</sup>). Grassland coverage consisted of plants with non-woody elements, such as grasses and forbs. These vegetation coverage elements were identified across the grazing paddocks utilized by cattle from the satellite images obtained.

After identification, the exact coverage of each vegetation category was calculated and expressed as a percentage of the total area. In cases where buildings and crops were identified, these were marked as “other” and their areas were removed from the sum of the total area.

## 2.4 Assessment of animal welfare indicators

Sixteen individual measurements were selected to address the four welfare principals established in the Welfare Quality® protocol (WQ 2009). The selection of welfare measures was done taking into account a previous protocol (Huertas et al. 2009), the feasibility to measure each indicator in the systems evaluated, and the relevance of

these indicators as a reflection of dual-purpose cattle in the humid tropics and the percentage of tree coverage. The welfare measures chosen were body condition, cleanliness of udder, flank/upper legs and lower legs, lameness, integument alteration, nasal discharge, ocular discharge, hampered respiration, diarrhea, vulvar discharge, ectoparasites, coughing, sneezing, agonistic behaviors, and avoidance distance.

All animals in each herd were evaluated as follows (WQ 2009):

- Body condition: focal sampling based on visual criteria with rear and flanks as reference. Ranks were assigned as follows: 0 = very lean, 1 = regular body condition, 2 = very fat.
- Cleanliness of udder, flank/upper legs and lower legs: observation of a random side of the body and the back. Presence or absence of plaques of dirt was recorded in each one of the mentioned areas.
- Lameness: evaluated when individuals left the milking parlor using weight bearing, timing, and rhythm of steps as indicators. It was ranked as follows: 0 = not lame, 1 = lame, 2 = severely lame.
- Integument alterations (injuries, inflammation and alopecia): observation of five areas from of a randomly selected side of the body from 2 m. The areas were hindquarter, tarsus, flank/side/udder, carpus and neck/shoulder, and back. Presence or absence of integument alterations was evaluated in each of these corporeal areas.
- Presence or absence of each health indicator: nasal discharge, ocular discharge, hampered respiration, diarrhea, vulvar discharge, and ectoparasites.
- Coughing and sneezing: mean number of coughs/sneezes per animal per 15 min.
- Agonistic behaviors: continuous recording of head butts and displacements observed in the herd from a high point of the pen or grazing paddock. Evaluation areas were divided in visual segments containing approximately 50% of cows and were done by one person per segment. Observation time varied according to the activities of each ranch; therefore, calculations were made using averages of head butts/cow/h.
- Avoidance distance: observers approached cows slowly (one step/2 s) with one arm stretched forward at a 45° angle to attempt to touch the muzzle. Motion was continued until the animal was touched, bended the neck, or moved away. Number of cows touched was recorded and when untouched, flight distance (distance between hand and muzzle at the time of withdrawal) was estimated.

To avoid observer effects, experimenters spent a 2-month training period where observations and measurements were standardized.

## 2.5 Statistical analyses

In order to explore possible correlations between welfare indicators and tree coverage, we performed a Spearman correlation test, obtaining a numerical coefficient in the range of  $-1$  to  $1$ , to indicate the type of associations (negative or positive) between variables. Combined welfare measures such as injuries (composed by lameness and integument alterations) and agonistic behavior (consisting of head butts and displacements) were analyzed separately. To assess the effects of ranches with high and low tree coverage (disregarding distribution) on welfare measures, a Mann-Whitney test was performed, which compared values for ranches with tree coverage  $> 10\%$  (ranches J1, J2, M2, M1, and V2) against ranches with tree coverage  $< 10\%$  (ranches S2, C2, C1, V1, and S1). Statistical analyses were performed using IBM SPSS Statistics version 20.0 for Windows.

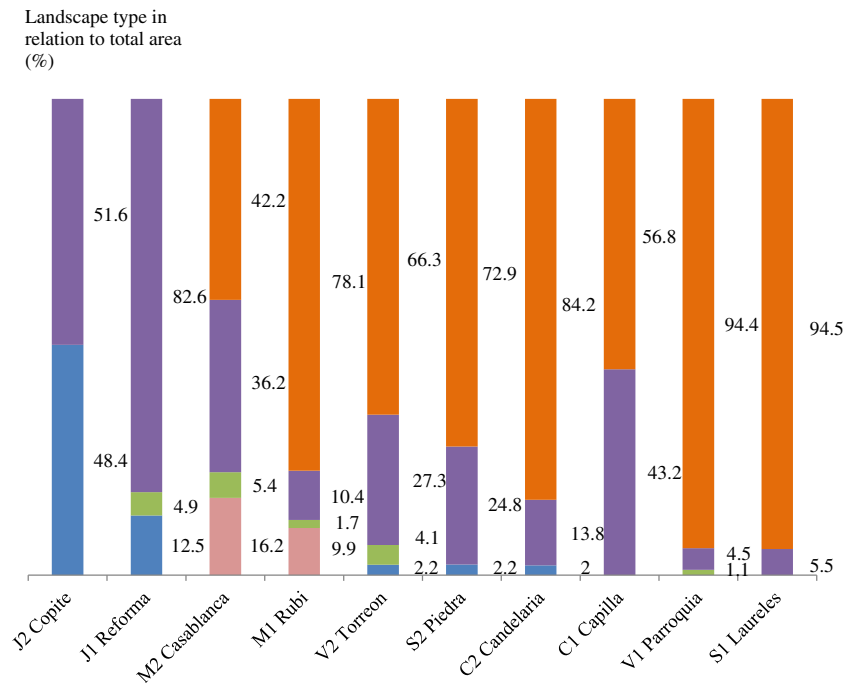
## 3 Results and discussion

### 3.1 Analysis of landscape units

Total area, tree coverage was obtained for each ranch. The indicator percentage of tree cover showed a large variability between ranches (J2 = 52.42%; J1 = 31.38%; M2 = 26.19%; M1 = 12.87%; V2 = 11.44%; S2 = 6.66%; C2 = 6.64%; C1 = 6.40%; V1 = 2.71%; S1 = 1.99%). Wooded grassland was present in all ranches; however, it was highly variable. The second most prominent landscape type was “grassland,” which was present in eight ranches and had a percentage range of 94.52% in ranch S1 to 42.19% in ranch M2. Forest fragments were present in 50% of ranches; however, the percentage was low, with the exception of ranch J2 (48.35% of the total area). Live fences were present in five ranches with a range of 5.42% in M2 to 1.12% in V1, being the smallest and narrowest range of landscape unit found. Riparian forest was only found in M2 and M1 (16.20 and 9.89% of total area, respectively) (Fig. 2). Since all ranches tested had wooded grassland, the percentage of tree cover in this landscape unit was analyzed. According to the established wooded grassland tree coverage criteria, five ranches had low levels of tree cover (from 7.94 to 13.17%) while the rest were high (J1, 16.91%; S2, 16.38%, C2, 30.95%; V1, 32.25%; S1, 32.25%) (Fig. 3).

The tree coverage analysis revealed different landscape compositions with a variety of possible implications for sustainable management. Having the highest percentage of forest fragments and tree coverage, ranch J2 could favor ecosystem services; nonetheless, an excess of forest fragments in a pasture could generate competition between grasses and trees for light, water, and nutrients (Dias-Filho 2000; Harmand et al. 2003; Kephart et al. 1992; Ong et al. 1991; Rao et al. 1998). A solution for this potential issue is the combined use of

**Fig. 2** Percentage of landscape type in relation to total area (100%) for each ranch. Landscape types: Grassland (orange), wooded grassland (purple), live fence (green), riparian forest (pink), forest fragment (blue)

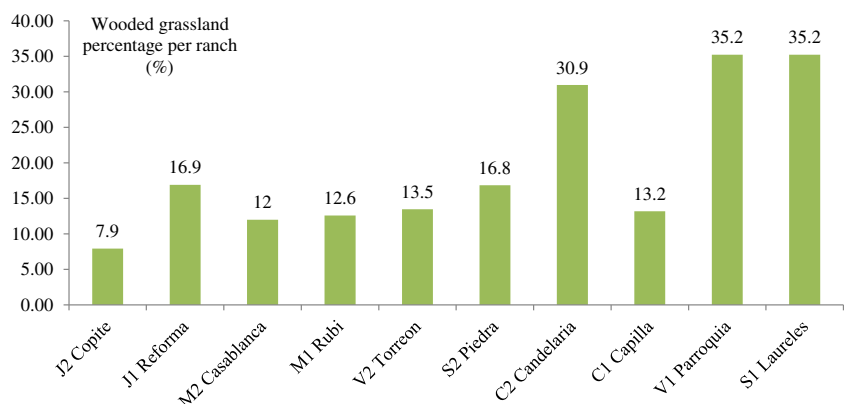


leguminous trees that increase soil nitrogen (Power et al. 2003; Fernández et al. 2002; Durr and Rangel 2000; Esquivel 2007) and the utilization of species of shade-tolerant grasses able to grow properly despite high canopy density (Carvalho et al. 2002; Bhatt et al. 2002). Thus, botanical surveys are identified as an important tool to define the real productivity of landscapes with high tree coverage.

Ranches J1 and M2 had tree coverage percentages considered as SPSs (Betancourt et al. 2003; Ibrahim et al. 2011; Montagnini 2009; Sáenz et al. 2006). In addition, ranch M2 had a percentage of riparian forest, which is a landscape related to the prevalence of endemic plants (living organism is described as both native and restricted to a particular geographical region, Masseti, 2009) in agricultural areas where this kind of forest has been preserved (Harvey et al. 2006; Mendoza et al. 2007). Riparian forest is also related to the conservation of bats in combination with linear

elements such as live fences (Verboom and Huitema 1997; Limpens and Kapteyn 1991). Ranches M1 and V2 had tree coverage percentages (below 13%) that cannot be considered SPSs (Betancourt et al. 2003; Ibrahim et al. 2011; Montagnini 2009; Sáenz et al. 2006). Nonetheless, this value is relatively high compared to other Mesoamerican ranches where many pastures have less than 10% of tree coverage (Harvey et al. 2006). Other ranches such as S2 and C2, with even lower percentages, also have vegetation features such as live fences, which are extremely important, providing connectivity and allowing the construction of networks in fragmented landscapes (Chacón and Harvey 2008; Harvey et al. 2006). Therefore, this general analysis of tree coverage percentage of ranches in the region reveals a clear opportunity to implement plans to increase their tree component, using tools like live fencing, which is a strategy already present and common in Veracruz (Bautista Tolentino 2009).

**Fig. 3** Percentage of tree coverage in the wooded grassland distribution per ranch



**Table 1** Welfare measures obtained for score calculations correlated with landscape characteristics. *CC* correlation coefficient, *N* number of ranches included

Welfare measure	Spearman's correlation values	Total area (m <sup>2</sup> )	Total tree coverage (%)	Total herbaceous coverage (%)	Landscape feature in total area (%)		
					Live fence	Wooded grassland	Grassland
Cows with low body condition (%)	CC	-0.35	-0.64	0.64	-0.73	-0.13	0.36
	<i>P</i> value	0.32	0.049	0.049	0.02	0.72	0.31
	<i>N</i>	10	10	10	10	10	10
Cows that can be touched in the paddock (%)	CC	-0.3	0.6	-0.6	-0.11	0.9	-0.87
	<i>P</i> value	0.62	0.29	0.29	0.86	0.04	0.05
	<i>N</i>	5	5	5	5	5	5
Displacements frequency in the milking pen (displacements/cow/h)	CC	-0.71	-0.04	0.04	-0.21	-0.13	0.17
	<i>P</i> value	0.04	0.92	0.92	0.59	0.73	0.67
	<i>N</i>	9	9	9	9	9	9

### 3.2 Evaluation of animal welfare indicators and observed correlations

The presence of trees in a paddock can potentially impact animal welfare (Broom et al. 2013; Améndola et al. 2016) as suggested by the correlations found in this study. The percentage of cows with low body condition was negatively correlated with both total tree coverage and “live fence” ( $R_s = -0.64$ ,  $P < 0.05$ , and  $R_s = -0.73$ ,  $P < 0.05$ , respectively, Table 1). Furthermore, when low body condition was compared between ranches with a tree coverage higher than 10% with those ranches with a tree coverage lower than 10%, a significant difference was found (mean ranks 3.5 vs 7.5,  $U = 2.5$ ,  $P < 0.05$ ) (Table 2).

Trees are considered the most effective shade source due to their solar protection and radiation absorbance qualities (Armstrong 1994; Hahn 1982). The decrease in temperature produced by tree shade can increase grazing and browsing times, resulting in more dry matter intake and better body condition (Betancourt et al. 2003; Casasola Coto 2000; Pérez et al. 2008), as well as more affiliative interaction between cows (Améndola, et al., 2016). Additionally, leguminous trees produce leaves and pods that are highly palatable and are available in the dry season, when pastures are of low nutritional value (Aguilar and Condit 2001; Esquivel 2007; Ku Vera 2005; Ortega et al. 1998; Solorio-Sánchez et al. 2000). Although inconclusive and in great need of a botanical survey, the observed correlations between body condition, tree coverage percentage, and live fences could indicate a relation between tree shade and/or tree species with weight gain, which needs to be further confirmed in tropical livestock systems.

Cows without integument injuries had a higher mean rank in ranches with high tree coverage compared with low (mean ranks 7.4 vs 3.6,  $P < 0.05$ ) (Table 2). Integument alterations

and other important diseases in cattle are produced by skin parasites such as ticks (Brossard and Wikel 2004). In SPSs, the prevalence of birds and insects that feed on ticks can reduce the number of ticks in a given area (Murgueitio and Giraldo 2009). Additionally, skin lesions are positively correlated to restricted laying areas (Regula et al. 2004), making the access to good shaded lying surfaces a potential benefit for cattle (Bennett et al. 1985; Leme et al. 2005). Therefore, the

**Table 2** Welfare measures obtained for score calculations in selected ranches with high (ranches J1, J2, M2, M1, and V2) and low (ranches S2, C2, C1, V1, and S1) tree coverage compared with Mann-Whitney test. Only measures with comparable number of ranches for contrast were included

Welfare measure	Mean rank		U value	Z value	<i>P</i> value
	Ranches with high tree coverage	Ranches with low tree coverage			
Cows with low body condition (%)	3.5	7.5	2.5	-2.35	0.019
Cows without lameness (%)	6.5	4.5	7.5	-1.1	0.28
Cows without integument alterations (%)	7.4	3.6	3.0	-2.1	0.03
Cows that can be touched in the milking pen (%)	4.25	5.6	7	-0.74	0.46
Head butts frequency in the milking pen (head butts/cow/h)	5	5	10	0	1
Displacement frequency in the milking pen (displacements/-cow/h)	4.5	5.4	8	-0.49	0.62

correlations observed between low injuries' scores and high tree coverage could indicate a positive influence of trees by keeping low levels of skin parasites and providing shaded lying space. These tentative conclusions obtained through correlations can be further addressed on livestock systems in tropical environments.

The percentage of cows that could be touched in the paddock showed a positive relationship with percentage of wooded grassland in relation to the total area and a tendency for a negative relationship with the percentage of grassland ( $CC\ 0.9$ ,  $P < 0.05$  and  $CC\ -0.87$ ,  $P = 0.05$ , respectively) (Table 1). Due to unexpected events determined by the timing of daily activities occurring in each ranch which influenced the access to paddocks, the number of production units tested for avoidance distance in the paddock was reduced and differences between ranches with high or low tree coverage for this variable were not found.

Avoidance reaction tests may have a different impact on the behavior to be evaluated when performed in different environments (Waiblinger et al. 2003), since the nature and magnitude of the behavioral and physiological reactions can differ substantially if tested in situations that allow or restrict flight from humans (Jones 1996). Therefore, a possible explanation for the correlations observed could be related to the space available to flee, which is reduced due to the presence of tree coverage. An alternative yet highly tentative interpretation could be related to the effects of temperature on cortisol levels and fear. Cortisol in cattle increases with heat (Faure et al. 2004). In female water buffaloes (*Bubalus bubalis*) kept in SPSs, lower cortisol levels are present (Silva et al. 2014). Broilers have shown more fear-related behaviors when exposed to high temperatures ( $38 \pm 1\ ^\circ\text{C}$  for 3 h) compared to those unexposed (Altan et al. 2003), suggesting a relation between cortisol, high temperatures, and fear. The present study does not provide evidence to conclude the existence of such mechanism in cattle. However, the correlations observed and the effects of heat on other production animals pave the way to further investigate this issue in tropical cattle. Furthermore, the flight distance test used in this experiment would require further research addressing the environmental variables that could affect the avoidance behavior in cattle, which could be related to climatic and other spatial conditions.

Displacement bouts at the milking pen had a negative correlation with the total area of pasture ( $CC\ -0.71$ ,  $P < 0.05$ ) (Table 2). This correlation could provide evidence on the need of appropriate individual space to limit negative social interactions (Le Neindre et al. 2004; Torres et al. 2009). Nonetheless, such interactions are highly complex and need a more detailed analysis.

The presence of SPSs in Latin-American and the benefits they produce by increasing environmental services, biodiversity, and reducing deforestation rates have been previously recognized (Bautista Tolentino 2009; Broom et al. 2013).

This study is a meaningful addition to the study and implementation of SPSs, as it is the first to evaluate landscape design and the improvements on animal welfare indicators derived from this feature by the use of a novel approach that integrates the use of GIS and animal welfare protocols. Improvements on animals' well-being in a sustainable manner can have positive effects on livestock production while preserving characteristics that contribute to the protection of main environmental features.

## 4 Conclusions

Given the known advantages of SPSs on the preservation of environmental services and the decrease of deforestation, this study aimed to contribute to the existing knowledge by elucidating possible connections between tree coverage and animal welfare indicators that were possible to measure in 10 Ranches of Veracruz, Mexico. The novel methodological approach with the inclusion of landscape analysis exemplified the use of these tools in the decision-making process for sustainable management and identified tree coverage percentages that have some relation with potential silvopastoral features. Ranches J1 and M2 had tree coverage characteristics that could be linked with sustainability.

Tree coverage was correlated positively with body condition due to the effects of shade and the possible existence of leguminous trees, which needs to be further evaluated. Reductions in integument injuries in ranches above 10% of tree coverage highlight the possible role of ecological cycles in areas with high tree coverage which could aid to promote the reduction of ticks and by increasing the availability of laying space. These hypotheses should be proven with subsequent studies. Avoidance distance showed interesting correlations with tree coverage that could be related to the space available to flee.

The inclusion of these evaluation tools in livestock systems will result in a clear framework for the generation of methodologies to implement and monitor SSPs in Central America, where the relationship between landscape features and animal welfare indicators is fully acknowledged and utilized to improve production.

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