Effects of pasture tree cover on cattle behaviour in a small-scale farming system in Rivas, Nicaragua

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Master of Science Thesis by Svein R. Hetland

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Preface

This study was carried out as a part of the SILPAS (Silvopastoralism) project, a cooperation between Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Norwegian University of Life Sciences (UMB), Hedmark University College (HiHdm), Norwegian University of Science and Technology (NTNU) and the Norwegian Institute for Nature Research (NINA). The goal of the project was to gain knowledge regarding silvopastoral practises in rural areas of Nicaragua in order aid farmers in increasing productivity and to promote the implementation of more sustainable farming practises.

This thesis was written at the Department of Natural Resource Management at UMB, Ås. Field work was carried out in Mata de Caña and Cantimplora in the region of Rivas, Nicaragua. Thank you, Muhammad, and all the other staff members at CATIE who made my stay possible.

I would sincerely like to thank my supervisors Stein and Christina for their dedicated efforts, honest comments and good guidance. Without you, this would not have been possible. Thank you Justin for joining me on this amazing trip and keeping me sane amongst all the craziness! A great big thank you goes out to Marlon, Edgardo and all the crazy people in Mata de Caña, you made my stay in Nicaragua an unforgettable experience! My parents deserve all the credit in the world for their immense support and encouragement. Thank you! And last but not least, a sincere thank you to all the friends I made along the way, for all the deep conversations, and good laughs, and for reminding me that life isn't all work and no play.

I would like to dedicate this thesis to my wonderful niece, Maya. May you grow up to be as fond of nature as I am.

Abstract

Rapid population growth and poverty with the resulting over-exploitation of land, threatens to further degrade land in rural areas of Nicaragua. Silvopastoral systems combine woody perennials and pastoralism and holds great promise for an increase in the sustainability of farming practises in these areas. This study investigated the effect of pasture tree cover with respect to different aspects of cattle behaviour, in two separate areas in Rivas, Nicaragua. Cattle behaviour was recorded in 15 different paddocks belonging to 7 different farmers using the instantaneous scan sampling technique. Canopy cover was found to have significant positive effects on energy conserving behaviours (ruminating and standing), while having a significant negative effect on high-activity behaviours (grazing and walking). Canopy cover had no significant effect on the level of resting. Some indications were found that there might be a social aspect affecting several of the behaviours. Canopy cover interacted significantly with several of the independent variables altering their effects on a given behaviour, with various degrees of canopy cover.

Key words: canopy cover, cattle behaviour, interactions, shade, silvopastoralism

Sammendrag

Kraftig populasjonsvekst og fattigdom, med den påfølgende overutnyttelse av landområder, truer med ytterligere utarming av jorda i grisgrendte strøk i Nicaragua. Jordbrukssystemer som kombinerer beite med trær på beitemarkene har store muligheter til å øke bærekraftigheten til jordbruksmetoder i grisgrendte strøk. Denne studien fokuserte på effekten av tredekke på beitemarkene på forskjellige deler av kyrs atferd på to separate områder i Rivas regionen i Nicaragua. Kyrenes atferd ble studert ved hjelp av ”instantaneous scan sampling” teknikk i 15 forskjellige innhegninger tilhørende 7 forskjellige gårder. Tredekket hadde en signifikant positiv effekt på energibevarende atferder (tygge drøv og stå), mens det hadde en signifikant negativ effekt på mer energikrevende atferder (beite og gå). Tredekket hadde ingen signifikant effekt på nivået av hvile. Det var noen indikasjoner på at sosiale forhold kunne være med på å påvirke enkelte av atferdene. Tredekket hadde signifikante interaksjoner med flere uavhengige variable, og endret deres effekt på en gitt adferd ved forskjellige grader av tredekke.

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Introduction

Increased land use pressure raises concerns regarding environmental degradation in rural areas of Central America (Muschler & Bonnemann 1997). Rapid population growth of up to 2.9% annually and increased poverty in the area result in over-exploitation and are considered the main driving forces behind the environmental degradation (CATIE 1994). Emphasis has been put on maintaining and implementing more sustainable farming practices, and many studies have been conducted attempting to find optimal practises for the individual areas (Muschler & Bonnemann 1997).

Silvopastoralism, an agroforestry system combining woody perennials and pastures, hold great potential for reducing the land degradation, at the same time as providing several benefits to the farmers (Ibrahim et al. 2004; Muschler & Bonnemann 1997; Nair 1985). Silvopastoral systems have the potential to increase diversity, decrease erosion and increase nutrient retention at the same time as providing shade (Dunn 2000; Eichhorn et al. 2006; Gregory 1995; Young 1989).

The effectiveness of different agroforestry practises are often related to local conditions such as the type of environment, soil, vegetation, and the cattle breed used by the farmers. By gaining a better understanding of the factors important for the optimal implementation of silvopastoral systems and adapting them to the local conditions, farming practises can be made more sustainable and pasture quality increased, effectively reducing the risk of further land and forest degradation (White et al. 2001).

Rapid population growth cause land to become overexploited and can lead to significant land degradation (CATIE 1994). Extensive deforestation and a high degree of soil compaction by cattle trampling, can easily transform soft absorbent soil into a hard pan, significantly reducing the soils ability to absorb water (Williams & Chartres 1991). Instead, water runs on top of the soil, carrying with it surface mould, seeds, manure, sand etc. This leads to increased erosion and nutrient runoff which in turn reduces the sustainability of the farming practises and reduce the productivity of the pastures. Trees are effective erosion reducing agents. By maintaining a certain degree of tree density in the pastures, the ability to combat erosion and maintaining productivity increases (Descroix et al. 2001; Pimentel & Kounang 1998).

In addition to being effective in reducing erosion, certain tree species provide tree fodder which can provide livestock farmers with an invaluable source of protein in times of water scarcity when overall fodder production is low (Razz & Clavero 1997; Thapa et al. 1997).

Tree fodder from these trees reduce the need for supplements for the farmer and has the potential to significantly increase milk production (Paterson et al. 1998).

One of the main benefits of introducing trees into the pastures is the protection they provide from environmental stress. In temperate areas trees act as shelter against cold stress such as wind chill and precipitation, while in tropical areas cattle use trees as shade in order to reduce heat stress induced by high temperatures and high levels of solar radiation (McArthur 1991; Tucker et al. 2007). Several studies have shown a preference for shaded areas amongst cattle when temperature, humidity and solar radiation is high (Roath & Krueger 1982; Tucker et al. 2008). Heat stress is a major concern for cattle farmers in tropical areas. Cattle loose heat by convection and evaporation to the air passing through the respiratory system, and by diffusion through the skin (Flamenbaum et al. 1986; McArthur 1991). In this way, cattle are able to maintain a fairly constant body temperature. When ambient temperatures increase above 25 $^{\circ}$C heat loss through convection is reduced and heat loss through evaporation becomes the main way to control body temperature (Flamenbaum et al. 1986). However, when humidity levels are high, evaporation becomes restricted causing body temperature to increase above normal levels. Controlling the amount of solar radiation by the use of shade therefore becomes an important way to reduce heat stress (Mader et al. 1999; McArthur 1991). Shade has been found to lower cows respiration rate and core body temperatures (Blackshaw & Blackshaw 1994), and improve milk yield, milk fat yield, reduce mastitis, conception rates and growth rates in grazing cattle (Fisher et al. 2008; Flamenbaum et al. 1986; Gregory 1995; McIlvain & Shoop 1971). A study conducted by Ravagnolo & Misztal (2002) in two different sites in Georgia, USA, found a reduction in milk production under relatively high levels of THI.[1] However, heat tolerance varies with the breed and coat colour, as some breeds are better adapted to high temperatures or radiation than others (Blackshaw & Blackshaw 1994; Tucker et al. 2008).

Some studies have indicated that competition over water between trees and surrounding vegetation may occur in silvopastoral systems (Dulormne et al. 2004; McIntyre et al. 1997). This could potentially reduce the productivity of the pastures in times when water is a limiting factor and provide cattle with less grass on which to feed. Farmers concerned with maximizing production will then have to weigh the potential loss of productivity due to vegetation competing with trees, against the benefits from reduced heat stress in the cattle.

[1] Temperature Humidity Index is a formula combining the effect of temperature and humidity to give the effect of environment on human comfort.

Pasture tree cover has the potential to reduce the solar radiation load on cattle, thus making them less prone to heat stress. However, little is known about the different aspects of cattle behaviour in relation to trees in the pastures, and whether the degree of canopy cover alters behavioural patterns. Thus, this study investigates the behaviour of cattle in pastures with varying degrees of tree cover.

Methods

Study area

Observations were conducted in 15 different pastures at 7 different farms. The farms were located in the areas of Mata de Caña (11° 26´ N, 85° 58´ W, 150 m.a.s.l.) and Cantimplora (11° 36´ N, 85° 58´ W, 100 m.a.s.l.) in the district of Rivas in South-West Nicaragua (Fig.1). The climate in lowland areas of southern Nicaragua is tropical with an average annual temperature fluctuation between 25.5 °C and 27.7 °C and about 1345 mm of precipitation (Table 1). The study area consisted mainly of semi-open pastures with surrounding dry forest (Sánchez et al. 2004). There is considerable monthly climatic variation with precipitation ranging from 3 mm in March to 265 mm in September. The rainy season lasts from May until November (Table 1).

Fig. 1. A map of Nicaragua with the district of Rivas marked in Blue. The study area was located in the north-central part of Rivas.

Table 1. Mean maximum temperatures (°C), mean temperatures (°C), mean monthly precipitation (mm), and average number of rainy days in Rivas, Nicaragua from 1961-1990 (H. K. Observatory, 2010).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Maximum Temperature (°C)	28.7	26.6	30.9	31.8	31.7	30.0	29.5	29.8	29.8	29.5	29.1	28.7
Mean Temperature (°C)	25.5	26	27	26.4	27.7	26.7	26.4	26.6	26.2	26.3	26.1	25.6
Rainfall Amount (mm)	8.0	4.0	3.0	10.0	172.0	225.0	151.0	181.0	265.0	209.0	87.0	30.0
Days with Rain	7.4	8.1	7.9	7.7	6.3	4.7	4.8	5.2	4.9	5.6	6.2	6.7

Farm practices

The farms included in this study were mostly small-scale cattle farms. The number of lactating cattle on each farm ranged from 4 to about 40 with most of the farms having between 10 and 25 cattle (Table 2). The farms were dual purpose farms with cattle used for both dairy and beef production. Four farmers kept cattle in a holding pen at the farm during night to avoid cattle theft. Milking usually took place between 06:30 and 10:00. After milking, the cattle were let back out into the pastures. Cattle kept in pasture during night were collected for milking early in the morning, and returned to the pasture around mid-day. With the exception of two farms, the cattle were kept in the same pasture for the entire day. The other two farmers kept the cattle in one pasture in the beginning of the day, took the cattle back to the farm for water, and into another pasture for the remainder of the day. In total three farmers took the cattle back to the farm in the middle of the day for water. None of the farmers had open access to water in the pastures. Some farmers would rotate between pastures every day, while others would keep the cattle in the same pasture for 1 – 2 weeks before rotating. The two farmers who changed pastures in the middle of the day often kept calves together with their mothers in the beginning of the day, and keep them apart for the remainder of the day.

Table 2. Size (ha), no. of trees, total canopy cover (m^2ha^{-1}), % cover, diversity and the average no. of lactating cattle recorded during each observation in the 15 pastures included in the study.

Farm	Pasture	Size	No. of trees	Total canopy cover	% Cover	Diversity	Average no. cattle / recording
1	A	3.68	14	1101.89	2.99	0.80	5
	B	1.22	103	1873.45	15.36	0.24	5
2	C	5.75	218	4151.90	7.22	0.90	9.89
	D	3.92	215	4357.52	11.12	0.93	9.89
3	E	1.00	129	5677.72	56.78	0.91	4
	F	1.47	211	5771.89	39.26	0.82	4
	G	0.46	112	2163.63	47.04	0.82	4
4	H	3.43	70	2246.94	6.55	0.63	12
5	I	1.79	43	930.93	5.20	0.79	18.59
	J	3.69	66	6741.56	18.27	0.86	18.59
	K	2.44	50	881.56	3.61	0.80	18.59
	L	1.48	90	4562.6	30.83	0.91	18.59
6	M	9.5	128	4965.8	5.23	0.91	37.33
7	N	6.36	43	1778.67	2.80	0.75	23.73
	O	5.46	153	7022.62	12.86	0.91	23.73

A total of 10 different breeds were kept by the farmers. The breeds were both pure breeds and crossbreeds. The main breeds kept were purebred Brahmans, followed by a Brown Swiss–Brahman cross, Simmental-Brahman cross and Indo Brazilian Zebu. All breeds either originated from the South-Asian breed *Bos indicus*, or were crossed with breeds originating from it.

The pastures selected for this study were selected from farms with close to natural pastures, a minimum of 4 lactating cattle and a cooperative farmer. Maintenance work in the pastures consisted mainly of manual cutting of bushes and undergrowth using machete. The pastures varied in size from 0.46 ha to 9.50 ha with an average size of 3.44 ha (Table 2). A database was generated to include all trees with a diameter larger than 5 cm at breast height (DBH). A total of 1650 trees of 59 different species were recorded in the pastures used in this study. The Simpson diversity (1-λ) of trees in the pastures ranged from 0.24 to 0.93 with a mean of 0.80 (Table 2) (Simpson 1949).

The most abundant tree species was *Myrospermum frutescens* (n=293) while *Guazuma ulmifolia* was the only species found in all 15 pastures. *Guazuma ulmifolia* also had the largest total canopy cover (7537.91 m^2) (Table 3).

Table 3. The 10 most abundant (found in the most no. of pastures) and frequent tree species (total no. of recorded trees in all pastures), and the tree species providing the most cover (total cover provided by all trees in all pastures in m^2)

Most abundant (no. of past.)		Most frequent (no. of ind.)		Most cover (total cover in m^2)	
Guazuma ulmifolia	15	*Myrospermum frutescens*	293	*Guazuma ulmifolia*	7537.9
Myrospermum frutescens	13	*Diphysa americana*	144	*Enterolobium cyclocarpum*	6728.6
Cordia alliodora	12	*Guazuma ulmifolia*	141	*Myrospermum frutescens*	5853.8
Gliricidia sepium	11	*Cordia alliodora*	124	*Diphysa americana*	3825.4
Casearia corymbosa	11	*Spondias purpurea*	98	*Cordia alliodora*	2752.9
Cordia dentata	10	*Cordia dentata*	86	*Tabebuia rosea*	2354.3
Simarouba amara	10	*Tabebuia rosea*	69	*Gliricidia sepium*	2188.0
Thouinidium decandrum	10	*Simarouba amara*	58	*Simarouba amara*	2052.6
Spondias purpurea	9	*Gliricidia sepium*	45	*Byrsonima crassifolia*	1894.0
Tabebuia rosea	9	*Acrocomia mexicana*	44	*Cordia dentata*	1839.5

Tree database

As a part of the SILPAS (Silvopastoralism) project, of which this study is a part, a database comprising a total of 47 pastures from 12 farms was being generated. In order to generate the database the borders of each pasture was plotted using a GPS with the map datum NAD27. Only trees with a diameter at breast height (DBH) greater than 5 cm were included in the database. For each tree the species name, DBH, total height, canopy height, mean canopy diameter and GPS location was recorded. The height of the trees was recorded using an inclinometer. The mean canopy diameter was calculated using the longest transect and the one perpendicular to it. A note was made for whether the tree was a single standing tree, part of a group, or a live fence tree. Trees were defined as being part of a group if there was a gap of less than 1 m from the tree to a neighbouring tree with a DBH larger than 5 cm. Live fence trees were defined as being trees with a distance of less than 1 m to the nearest fence in a line of interconnecting trees (less than 1 m gap between canopies) stretching at least 100 m. The borders of riparian areas and dense forest clusters were plotted using a GPS, but trees were not individually recorded as canopies were considerably overlapping. Out of the 47 pastures 15 pastures from 7 farms were selected for this study.

Behavioural recording

The study was conducted using instantaneous scan sampling (Altmann 1974). Between 2 and 6 scan samples were recorded during each hour of observation. Data was gathered throughout the day between 07:30 and 17:00. Data on shade use was gathered between 10:30 and 13:40 when the degree of shade was approximately equal to the degree of canopy cover. Sunrise occurred approximately 05:30 and sunset approximately 17:30. Sampling periods would last up to 9 hours. A total of 144 scan samples were collected over the course of 10 weeks. The recorded behaviour was divided into 7 behavioural categories (Table 4) which made out the response variables. In addition it was noted whether the behaviour took place in the shade of trees or outside of the shade.

Table 4. Behavioural categories making up the response variables

Grazing	This behaviour included behaviour where the cow was visibly grazing, or standing still with the head tilted towards the ground, walking slowly with the head tilted towards the ground with less than 10 seconds between each bite.
Ruminating Standing	Standing still with the head up from the ground with the mouth visibly moving in a ruminating pattern.
Ruminating Lying	Lying still with the head up from the ground with the mouth visibly moving in a ruminating pattern.
Walking	Moving more rapidly with the head lifted up from the ground with duration of more than 10 seconds.
Standing	Standing still, not ruminating.
Resting	Lying still, not ruminating.
Other	All behaviour not covered by the above categories such as interactions with other animals.

Cattle showed some reaction to the presence of an observer in the pasture in the beginning of the study period. The effect diminished towards the end of the study period as cows became more accustomed to the presence of the observer. Caution was always taken to disturb the cattle as little as possible and observations were made at distances far enough to keep the disturbance effect at a minimum level at the same time as being able to differentiate between behaviours. Binoculars were used when necessary. For each scan sample environmental variables were recorded using a Davis Wireless Vantage Pro2 weather station.

Analysis

The size of the pastures was the basis for calculating the degree of canopy cover. Due to the lack of canopy data for the riparian areas and dense forest clusters, and the fact that cattle did not move into them (personal observation), these areas were not considered as part of the pasture and subtracted from the total size of the pastures. Riparian areas and dense forest clusters made up a relatively small proportion of the total canopy cover, and the exclusion of these areas can be considered conservative. Areas were calculated using GPS coordinates. The canopy cover provided by live-fence trees was divided by two since only about half the canopy was inside the pasture. 'Time since sunrise' was set to be hours after 06:00 and 'time since entrance' was set to be hours after cattle were let back out into the pastures. Temperature and humidity was combined into a single variable, Temperature Humidity Index (THI), which is a widely used index when studying heat stress in cattle (Bouraoui et al. 2002). THI was calculated using the formula:

$$THI = T - (O.55 - 0.55RH)(T - 58) \qquad (1)$$

where: RH = relative humidity

T = °F

For each behavioural category (Table 4), the number of cattle engaged in the behaviour and the number of cattle not engaged in the behaviour was monitored for each scan sample. The behavioural category 'other' yielded a mere total of 4 observations (mainly interactions between cattle) and was therefore excluded from the analysis. For analysis of the behaviours, the lmer function, which is part of the lme4 library in the statistical package R (http://www.r-project.org/), was used. The linear mixed-effect model deriving from it assumes binomial errors (Crawley 2007). I used the combined variable of the behaviour category (e.g.

animals grazing vs. not grazing) as the binomial response variable. To predict the probability of each behaviour occurring, a repeated measure analysis with pasture as the repeated random variable, and canopy cover, time since entrance (hours), time since sunrise (hours), cattle density (cattle ha^{-1}), THI (Temperature Humidity Index), UV (UV-index) and solar radiation (W/m^2) as fixed effects. Due to co-linearity between the independent environmental variables (THI, UV and solar radiation) and between the independent time-related variables ('time since sunrise', 'time since entrance') (Table 5), the variables yielding the best fit for each behavioural variable were used.

Table 5. Pearson correlation coefficients (ρ) and p-values of UV (UV-index), Solar radiation (W/m^2), THI (Temperature Humidity Index), Time since entrance (hour), and Time since sunrise (hour) measured in a cattle behavioural study in Rivas, Nicaragua.

	Solar radiation		**UV**		**THI**		**Time since entrance**	
	ρ	**p-value**	**ρ**	**p-value**	**ρ**	**p-value**	**ρ**	**p-value**
UV	0.87	p < 0.001						
THI	0.64	p < 0.001	0.62	p < 0.001				
Time since entrance	-0.03	p = 0.681	-0.15	p = 0.068	0.20	p = 0.016		
Time since sunrise	-0.14	p = 0.099	-0.31	p < 0.001	0.13	p = 0.120	0.70	p < 0.001

The most parsimonious model was selected by first fitting the maximum model, testing for over dispersion in the cases where quasibinomial errors were used, removing non-significant interaction terms and comparing models using ANOVA (analysis of variance) and Akaike Information Criterion (Crawley 2007). Only first-order interactions with canopy cover were included in the model, since canopy cover was the variable of main interest. Interactions were centred in order to avoid co-linearity between the interaction factor and the independent variable (Fürst & Ghisletta 2009). To avoid an excessive span in the numeric values for the independent variables, the values for solar radiation were divided by 100. This gave an odds-ratio value for solar radiation corresponding to an increase in 100 W/m^2.

Results

Average daytime THI values during monitoring peaked between 11:00 and 12:00 (Fig. 2). THI remained consistently high between 10:00 and 15:00 with values in excess of 82 (corresponding to 30°C, and 74% relative humidity). Solar radiation increased rapidly, reaching a peak of about 800 W/m^2 around noon before declining to approximately 0 around 17:00 (Fig. 3).

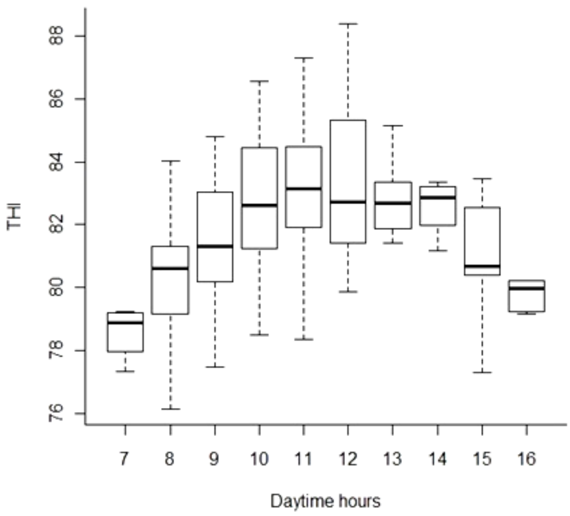

Fig. 2. Average daytime THI values measured measured in field on observation days (n = 78). Each value on the x-axis represents the time span between the given hour and the next, e.g. 'daytime hours' = 7 represents values gathered between 07:00 and 08:00.

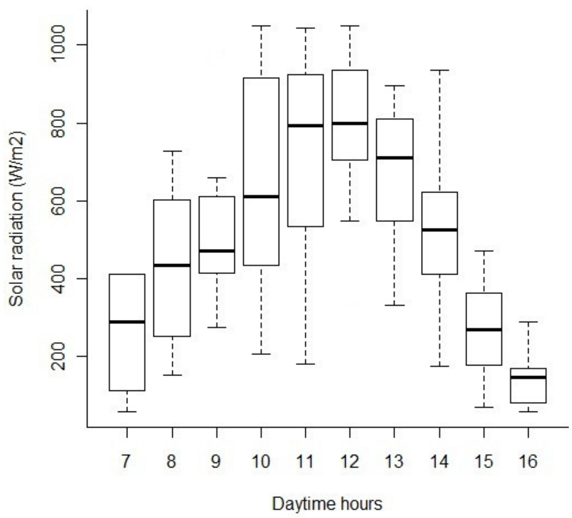

Fig. 3. Average daytime solar radiation values (W/m^2) measured in field on observation days (n = 78). Each value on the x-axis represents the time span between the given hour and the next, e.g. 'daytime hours' = 7 represents values gathered between 07:00 and 08:00

Four independent variables and two interactions significantly affected the probability of cattle being in the shade (Table 6). THI was the most significant independent variable, and the most determining variable with respect to the probability of cattle being in the shade, with a strong positive effect (odds-ratio = 1.74). Cattle being more likely to use shade when the degree of canopy cover increased (odds-ratio = 1.058) Both cattle density and time since sunrise had a negative effect on the probability of cattle being in the shade (odds-ratios of 0.91 and 0.96 respectively), however, while cattle density interacted negatively with canopy cover with respect to the level of shade use (odds-ratio = 0.992), the interaction between time since sunrise and canopy cover was positive (odds-ratio = 1.024).

Table 6. The effect of canopy cover (%), cattle ha^{-1}, time since sunrise (hours), THI (Temperature Humidity Index), and the interaction effects between canopy cover and cattle ha^{-1}, and canopy cover and 'time since sunrise' on the probability of cattle using shade (n = 69) in the time space between 10:30 in the morning and 13:40 in the afternoon. Interaction between canopy cover and THI was removed (Δ AIC = 1.6).

	Odds-ratio	S.E.	t-value
(Intercept)	1.383	0.060	7.6
Canopy cover	1.058	0.002	33.8
Cattle ha^{-1}	0.910	0.008	-10.5
Time since sunrise	0.960	0.012	-3.3
THI	1.740	0.010	92.9
Canopy cover : Cattle ha^{-1}	0.992	0.001	-16.1
Canopy cover : Time since sunrise	1.024	0.001	32.8
AIC			222.6

Four independent variables and one interaction significantly affected the probability of cattle grazing (Table 7). The probability of cattle grazing was strongly affected by THI with the probability decreasing with increasing levels of THI (odds-ratio = 0.696). Cattle grazed more later in the day (odds-ratio = 1.148) and less with increasing cattle density (odds-ratio = 0.949) and canopy cover (odds-ratio = 0.988). However, the interaction between cattle density and canopy cover was positive (odds-ratio = 1.011).

Table 7. The effect of THI (Temperature Humidity Index), time since sunrise (hours), cattle ha^{-1}, canopy cover (%), and the interaction effects between canopy cover and cattle ha^{-1} on the probability of cattle grazing (n = 144). Two interactions were removed in the following order: interaction between canopy cover and THI (Δ AIC = 1.9), interaction between canopy cover and time since sunrise (Δ AIC = 1.3).

	Odds-ratio	S.E.	t-value
(Intercept)	1.783	0.095	11.2
THI	0.696	0.003	-73.0
Time since sunrise	1.148	0.007	21.7
Cattle ha^{-1}	0.949	0.010	-5.1
Canopy cover	0.988	0.002	-6.8
Canopy cover : Cattle ha^{-1}	1.011	0.001	18.1
AIC			624.8

All the independent variables fitted in the maximum model were found to be significant when investigating variables effecting ruminating standing (Table 8). Cattle density and UV were the most determining independent variables, having a positive effect on the probability of cattle ruminating standing (odds-ratios of 1.094 and 1.090 respectively). Canopy cover had a positive effect on the probability of cattle ruminating standing (odds-ratio = 1.014). Cattle density, time since entrance and UV all interacted negatively with canopy cover (odds-ratios of 0.993, 0.994 and 0.996 respectively).

Table 8. The effect of time since entrance (hours), canopy cover (%), cattle ha^{-1}, UV (UV-index), and the interaction effects between canopy cover and cattle ha^{-1}, canopy cover and 'time since entrance', and canopy cover and UV on the probability of cattle ruminating standing (n = 144).

	Odds-ratio	S.E.	t-value
(Intercept)	0.055	0.001	-148.21
UV	1.090	0.003	36.43
Time since entrance	0.934	0.004	-14.80
Canopy cover	1.014	0.001	15.25
Cattle ha^{-1}	1.094	0.004	23.62
Canopy cover : Cattle ha^{-1}	0.993	0.000	-28.54
Canopy cover : Time since entrance	0.994	0.000	-23.51
Canopy cover : UV	0.996	0.000	-28.78
AIC			342.0

Also for 'ruminating lying' all the independent variables fitted in the maximum model were found to be significant when investigating the effects on ruminating standing (Table 9). Cattle ruminated lying less later in the day (odds-ratio = 0.8). Canopy cover, cattle density and THI were all found to have positive effect on 'ruminating lying' (odds-ratios of 1.035, 1.139 and 1.467 respectively). Canopy cover interacted negatively with the effect of cattle density (odds-ratio = 0.982) on 'ruminating lying' and positively with THI and time since sunrise (odds-ratio = 1.007).

Table 9. The effect of time since sunrise (hours), canopy cover (%), cattle ha^{-1}, THI (Temperature Humidity Index), the interaction effects between canopy cover and cattle ha^{-1}, between canopy cover and THI, and between canopy cover and time since sunrise on the probability of cattle ruminating lying (n = 144).

	Odds-ratio	S.E.	t-value
(Intercept)	0.094	0.002	-124.9
Time since sunrise	0.800	0.003	-63.5
Canopy cover	1.035	0.001	50.9
Cattle ha^{-1}	1.139	0.005	29.3
THI	1.467	0.004	133.6
Canopy cover : Cattle ha^{-1}	0.982	0.000	-62.9
Canopy cover : THI	1.007	0.000	39.8
Canopy cover : Time since sunrise	1.007	0.000	37.6
AIC			325.8

Three independent variables and one interaction significantly affected the probability of cattle walking (Table 10). Cattle were less likely to walk with increasing canopy cover (odds-ratio = 0.989). Cattle density had the greatest effect on the probability of walking and higher densities of cattle increased the probability of cattle walking (odds-ratio = 1.186).

Table 10. The effect of solar radiation (100 W/m^2), canopy cover (%), cattle ha^{-1}, and the interaction effects between canopy cover and solar radiation on the probability of cattle walking (n = 144). One ordinary variable and two interactions were removed in the following order: interaction between canopy cover and cattle ha^{-1} (Δ AIC = 1.8), interaction between canopy cover and time since entrance (Δ AIC = 1.0), and the single variable 'time since entrance' (Δ AIC = 1.2).

	Odds-ratio	S.E.	t-value
(Intercept)	0.013	0.000	-354.4
Solar radiation	1.035	0.002	20.3
Canopy Cover	0.989	0.001	-19.9
Cattle ha^{-1}	1.186	0.003	63.0
Canopy cover : Solar radiation	0.991	0.000	-91.0
AIC			175.2

Two independent variables and one interaction were found to significantly affect the probability of cattle standing (Table 11). UV had the greatest effect with the probability of cattle standing increasing with increased levels of UV. Cattle were less likely to be standing with increased canopy cover (odds-ratio = 1.008). There was a negative interaction between canopy cover and UV (odds ratio = 0.996).

Table 11. The effect of canopy cover (%), UV (UV-index) and the interaction between canopy cover and UV on the probability of cattle standing (n = 144). Two ordinary variables and two interactions were removed in the following order: interaction between canopy cover and cattle ha^{-1} (Δ AIC = 1.7), interaction between canopy cover and time since entrance (Δ AIC = 1.4), the single variable 'time since entrance' (Δ AIC = 0.7), the single variable 'time since entrance' (Δ AIC = 1.8) and the single variable cattle ha^{-1} (Δ AIC = 0.4).

	Odds-ratio	S.E.	t-value
(Intercept)	0.056	0.001	-218.6
Canopy cover	1.008	0.000	16.2
UV	1.112	0.002	58.6
Canopy cover : UV	0.996	0.000	-42.5
AIC			220.7

Three independent variables significantly affected the probability of cattle resting (Table 12). Cattle were less likely to be resting during high cattle densities (odds-ratio = 0.873), or later in the day (odds-ratio = 0.866). The main factor affecting the probability of cattle resting was THI, which had a very positive effect (odds-ratio = 1.431).

Table 12. The effect of cattle ha^{-1}, time since sunrise (hours), and THI (Temperature Humidity Index) on the probability of cattle resting. One ordinary variable and three interactions were removed in the following order: interaction between canopy cover and THI (Δ AIC = 1.8), the interaction between canopy cover and time since sunrise (Δ AIC = 0.6), the interaction between canopy cover and cattle ha^{-1} (Δ AIC = 0.9), and the single variable 'canopy cover' (Δ AIC = 0.9).

	Odds-ratio	S.E.	t-value
(Intercept)	0.032	0.001	-206.31
Cattle ha^{-1}	0.873	0.004	-33.57
Time since sunrise	0.866	0.003	-46.97
THI	1.431	0.002	181.02
AIC			250.2

Discussion

The aim of this study was to investigate the behaviour of cattle in pastures with varying degrees of tree cover. Results show a complex pattern of effects determining various aspects of cattle behaviour. Canopy cover was found to have a positive effect on the probability of cattle using shade, ruminating standing, ruminating lying, and standing. There was also a negative effect of canopy cover on the level of grazing and walking. In other words, cattle were more likely to be in the shade, ruminate or stand still if there was a large degree of canopy cover in the pasture, and less likely to be grazing or walking. The theory of resource allocation has been used to explain the evolution of resource conserving behaviour (Schütz et al. 2001). Cattle have evolved to reduce the level of high-activity behaviour such as grazing and walking, when exposed to extreme environmental conditions, in order to allocate resources to thermoregulation (Collier et al. 2009). However, this doesn't provide a sufficient explanation as to why the level of energy conserving behaviour was found to increase together with an increase in canopy cover, seeing as being in the shade in itself should provide relief from heat stress. In fact, one would expect cattle with less access to shade from trees to exhibit more resource conserving behaviours than cattle with ample access to shade. This might to some degree be explained by the fact that a higher degree of canopy cover provide larger areas of shade able to encompass more cattle, combined with the social nature of cattle. Langbein and Nichelmann (1993) found that cattle of a heat tolerant breed altered their breed specific behaviour when placed together with cattle of a less heat tolerant breed. The theory was that they did this in order to maintain group cohesion. When the cattle of the less heat tolerant breed sought shade, the cattle of the heat tolerant group would follow despite environmental conditions being below the limit for when they would normally seek shade.

Other studies have found that cattle have a clear preference for shaded areas when exposed to heat stress (Mitlöhner et al. 2002; West 2003). The positive effect of canopy cover on the level of shade use found in our study shows a non-linear relationship between the level of shade use and canopy cover with the subsequent increase in shade use being higher than the corresponding increase in canopy cover. If the cattle would have no preference for shade from trees, we would expect an increase in canopy cover to lead to an equally large increase in the degree of shade use. Thus, this indicates that cattle in our study consciously sought shade from trees.

The insignificant effect of canopy cover on the level of resting indicates that cattle will choose to rest irrespective of the presence of canopy cover.

Another interesting find in this study was the number of interactions between canopy cover and independent variables with respect to cattle behaviour. Although the odds-ratio values of interacting variables were usually quite low, the large variation in canopy cover (Table 2) makes the potential cumulative effect relatively large. Thus, canopy cover significantly alters the effect of a variable on a given behaviour as the level of cover increases. The interaction effects illustrates that one cannot simply look at the effect of one variable on a given behaviour without taking into account the surrounding environment.

Environmental variables (THI, UV and solar radiation) were found to be the most determining factors affecting most of the behaviour. While other studies have mostly focused on the effect of temperature, humidity and solar radiation on cattle behaviour (Langbein & Nichelmann 1993; Schottler et al. 1975), this study included the effect of UV. Surprisingly, UV seemed to cause cattle stand as UV was found to be the most significant environmental variable affecting the level of 'ruminating standing' and 'standing'. In comparison, the most significant environmental factor affecting the level of 'ruminating lying' and 'resting' was found to be THI. Also the time of day coincided for 'ruminating lying' and 'resting' indicating that these behaviours could effectively be grouped in the categories 'standing' and 'lying'. This has been done in previous studies (Langbein & Nichelmann 1993). However, the effect of cattle density differed significantly between the ruminating behaviours, and 'standing' and 'resting'. While the effect of cattle density was positive with respect to 'ruminating lying' and 'ruminating standing', the effect was negative or insignificant with respect to 'standing' and 'resting'. This might indicate that although the same environmental factors cause the cattle to stand or lie down, the act of ruminating is driven by a social aspect (Langbein & Nichelmann 1993).

Canopy cover had a positive effect on both of the ruminating behaviours and 'standing', while it was insignificant with respect to resting. However, when the level of canopy cover increased it interacted negatively with 'time since entrance' and 'UV' with respect to 'ruminating standing' while interacting positively with the same factors with respect to 'ruminating lying'. The result being that as canopy cover increases, UV is less likely to make cattle 'ruminate standing' and when they do 'ruminate standing' they do it at an earlier time of day, while an increase in canopy cover means that THI is more likely to make cattle 'ruminate lying' and cattle 'ruminate lying' later in the day.

Three farmers let the cattle stay in pastures during the night. The level of night-grazing was not investigated in this study, however, cattle spending nights in the paddocks have the potential to spend up to 60 % total daily grazing time grazing at night (Langbein &

Nichelmann 1993; Schottler et al. 1975). The farmers who kept their cattle in pastures during night were also the farmers with the largest number of cows. Milking of these cows was initiated later, as cattle would first have to be collected. At the same time the process of milking took longer, seeing as they had more cattle to milk. The result being that these cattle were let back out into the pastures at a later time. Explaining why the results show that cattle were grazing more in the afternoon than in the morning and ruminating more in the morning than in the afternoon. The cattle that had not been night grazing entered the pastures at an earlier time and were able to graze for a period of time before temperatures reached a critical level.

In this study THI values exceeded 78 throughout the entire day and during five hours in the middle of the day, the average THI value exceeded 82 (Fig. 2). Other studies have found that cattle ceased to feed for a longer period in the middle of the day, and instead sought ways to escape the sun (McArthur 1991; Tucker et al. 2007). Roath and Krueger (1982) studied the behaviour of grazing cattle on a forested mountainous range in the southern Blue Mountains of Oregon. They found that cattle were actively feeding in the morning, proceed to bed in a shaded area until mid or late afternoon before having another feeding session.

Blacsshaw and Blackshaw (1994) found that *Bos indicus* breeds and their crosses were better adapted to cope with heat stress than *Bos taurus* breeds. They attributed this to differences in metabolic rate, food and water consumption, sweating rate, and coat characteristics and colour. The superior heat regulatory capacities meant that *Bos indicus* breeds were able to maintain production in conditions where *Bos taurus* was not. All of the cattle included in this study were either *Bos indicus* or *Bos indicus*-crosses.

Excluding the effect of solar radiation, the thermoregulatory mechanisms of *Bos indicus* come into effect at THI levels of approximately 75 with increased respiration and vaporization rates (Brody 1956). At THI levels of approximately 87, thermoregulatory mechanisms begin to fail resulting in a decline in feed consumption, milk production, and body weight. With the added effect of high levels of solar radiation, the critical levels of THI are likely reduced.

This study gives indications of the effect of tree cover on various aspects of cattle behaviour. However, this study makes no attempt at predicting an optimal degree of tree cover in relation to milk production and weight gain in cattle. Although trees in the pastures have the clear benefit of providing cattle with shade, they provide the farmers with several potential benefits. Farmers are often have good knowledge of the direct benefits of different tree species and in addition to providing shade and fodder for the cattle, trees provide farmers with fence posts, timber and fruits (Cajas-Giron & Sinclair 2001). However, farmers are often also acutely aware of the ecological benefits of keeping trees in their pastures, and list e.g. food for birds as a reason for keeping trees (Harvey & Haber 1999).

Conclusion

The main goal of this study was to investigate the effects of canopy cover on different aspects of cattle behaviour. Results showed that cattle in rural areas of Rivas, Nicaragua, significantly alter their behaviour in response to environmental variables, probably due to heat stress. Canopy cover had a positive effect on energy-conserving behaviour such as ruminating and standing, and a negative effect on high-activity behaviours such as walking and grazing.

Previous studies have combined the behavioural categories 'ruminating standing' and 'standing' into a single category called 'standing', while the behavioural categories 'ruminating lying' and 'resting' have been combined into a single category called 'lying'. However this study found indications that there might be a social element affecting the decision to ruminate making the division into four behavioural categories meaningful.

Tree cover was found to have either positive or negative effect on all behavioural categories with the exception of 'resting'. In addition, canopy cover interacted significantly with several other variables, altering their effects on a given behaviour with varying degrees of tree cover.

Future research should focus on the effect of silvopastoral systems on the level of productivity, biodiversity and erosion. When making predictions on optimal farming practices, considerations must be made with respect to the use of night-grazing, tree-fodder as supplements and the importance of tree-products as fire fuel or an alternative income.

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