IMPACT OF SHADE TREES ON ANGUS COW BEHAVIOUR AND PHYSIOLOGY IN SUMMER DRY HILL COUNTRY: GRAZING ACTIVITY, SKIN TEMPERATURE AND NUTRIENT TRANSFER ISSUES

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Abstract

Increased farm production often comes at the expense of trees that limit pasture growth, hinder stock mustering and impede pivot irrigator movement. Further, some farmers believe that if animals use trees for shade, intake will decline and will production suffer. This trial quantified grazing time of cows in paddocks with and without space-planted willows that provide shade in summer. Cow movement was determined by GPS, activity (walking, standing, grazing, and lying) by Icetag®, and dorsal skin temperature with a button temperature logger. Button loggers were also placed on the tree trunk (shade) and in full sun. Cow movements, fences and water sources were displayed on GIS map layers overlying the farm's aerial photograph that showed trees in the 'shade' treatment. Time spent by cows within 0-5 m and 5-10 m zones centred on the trees was determined as an indicator of shade usage. Paddocks of 10–20 ha, with trees (2) or without trees (2), formed two reps. Each paddock grazed 6 monitored cows, with others added to standardise stocking at 2.1 cows/ha. The trial ran from 26 February to 16 March 2010 on a hill farm near Porangahau. Shade reduced maximum ambient temperature by 10˚C. Average temperature on the cows back at 2 PM was 40.8˚C for *No shade* and 36.8˚C for cows with S*hade*. Most grazing was between sunrise and sunset, with short bouts during the night. Cows often used shade from about 9 AM. Between 10 AM and 4 PM, from 30 to 70% of lying and 20 to 60% of standing time was within 10 m of the tree trunk. Shade cows grazed for 30-40 minutes longer than 'no shade' cows. As trees will potentially create critical source areas of nutrient and faecal pollution, judicious selection of tree species and their placement across hill slopes should minimise pollution of waterways, improve nutrient return across the slopes and potentially increase animal performance through reduction of heat stress.

Introduction

Within the Huatokitoki Sustainable Farming Fund project on the East Coast North Island, debate on whether animals offered shade would spend less time eating and, therefore, grow more slowly was one view held. Another view was that animal welfare should be the foremost consideration when developing farm plans. This question has implications throughout the New Zealand farming community, especially where farmers are consciously removing trees to grow more pasture or to make for easier management. In contrast, others are planting trees to stabilise soils prone to erosion, and to provide drought forage, provide summer shade or winter shelter (Charlton et al. 2007). Some farmers also want to provide improved ecosystems and corridors for wildlife movement across the landscape. It is clear that shade and shelter may result in increased localised pollution (critical source areas (CSAs)) where overland flow carries nutrients and pollutants to waterways and lakes.

This project used Angus beef breeding cows, with their calves, to provide behavioural data from replicated paddocks that either had, or did not have, space-planted willows. These data were linked to temperature measurements on the cows, weather and land contour data describing the paddocks, in an attempt to understand behavioural traits and as they may impact the risk of pollutants leaving the paddocks.

Site

Four 10 to 20 ha paddocks in very close proximity on the farm of the "Parson Estate", Bush Rd, Porangahau, were used. Two paddocks had 6 year-old (4-6 m high) widely space-planted willow trees whereas the others two paddocks had either one tree (over the boundary) or no trees from which cows could obtain shade. The trees would have provided more than enough shade for all animals at any one time.

Materials and methods

The trial site was on moderate to steep, summer-dry hill country. Cows were selected from a large herd of mature Angus cows (black coat colour), each with its calf. These were weighed onto the plots on 26 January 2011 and again when removed on 16 February. Each paddock was stocked at 2.1 cows/ha, with each paddock having 6 *monitor* cows (Plate 1). Locally manufactured GPS collars (Plate 1 #1) (Betteridge et al. 2010a; Betteridge et al. 2010b), programmed to record positions every second for 20 mins after which they were turned off for 20 mins, were fitted to all *monitor* cows. These cows also had an Icetag® (IceRobotics) fitted to the left rear leg (#2). These were programmed to download data at one minute intervals. These data were then manipulated to output the number of minutes per hour spent Lying, Standing, Walking or Grazing ((Aharoni et al. 2009). Four cows in Rep 1 *Shade* and Rep 1 *No Shade* had a rumen bolus (Kahne, New Zealand Ltd)(#3) to log temperature and rumen pH at one minute intervals (pH data not presented in this paper). Three monitored cows in each paddock had a WatchDog® (Spectrum Technologies Inc.) button temperature sensor, fitted inside a rubber bicycle tube, glued to the mid-point on their back (#4). These recorded an integral of metabolic and ambient temperature experienced by the cow at that position at 15 min intervals. Sensors on all cows recorded data over the full 21-day period, unless they failed beforehand. Rumen sensors were operational only over the last 14 days due to download difficulties at the end of the first week.

Paired ambient temperature readings were taken 2 m above ground on the shady side of a tree trunk, or on a peg 15 cm above ground level, some 4-6 m away on the sunny side of the tree, with the button temperature sensor. These paired readings were taken at 10 randomly located sites within one *Shade* paddock to indicate the potential benefit a cow might have by accessing shade during a hot day. A full meteorological station was positioned on a ridge and another in the sheltered gully of one paddock to describe the weather effects experienced by the animals.

A video surveillance camera was installed in one *Shade* paddock that had both a stock water dam and a water trough. This camera scanned briefly through two adjacent treatment paddocks but was programmed to observe the *Shade* paddock for about 50 min/hr time. Video recordings were continuous during daylight hours, with data transmitted back to the farm house where it was stored on a computer hard drive. It proved impossible to count cows under shade (black cows in dark shade) so we noted when cows visited the dam or water trough as an indicator of drinking frequency. The exact number of drinks could not be determined as the camera was not constantly looking at the one paddock and did not work at night.

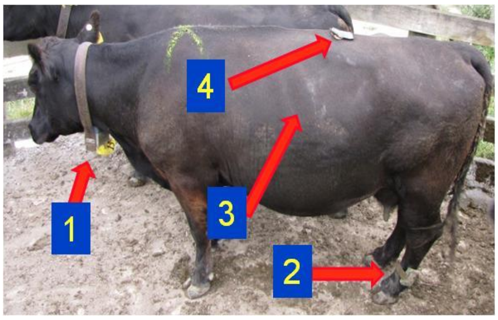

Plate 1 Sensors on beef cow:
1 – GPS collar;
2 – Icetag® motion sensor;
3 – Kahne® rumen temperature and pH sensor;
4 – Watchdog® button temperature logger.

To determine the use made of shade trees by the cows, ArcGIS® buffer zones of 0-5 m and 5-10 m were placed around trees in the *Shade* treatment. Icetag-defined activities of cows within these buffer zones during each hour of the day were determined and expressed as a percentage time spent in the buffer zones performing an activity compared to the respective total activity time spent during each hour (e.g. 50% of all lying time between 3 PM and 4 PM occurred within the buffer zones).

Results and discussion

Weather

Conditions were generally warm rather than hot during the trial. Mean 24-h temperature fluctuated between 15 and 24˚C with the maximum temperature exceeding 30˚C on only three days (Fig. 1). Night temperature was always <20˚C, reaching as low as 7˚C on 2 February. There was 28 mm rain during the trial, with 27 mm falling on 29 January. Wind run was highly variable, especially in the first week. Mean daily relative humidity ranged between 61 and 86% and averaged 77% over the three weeks.

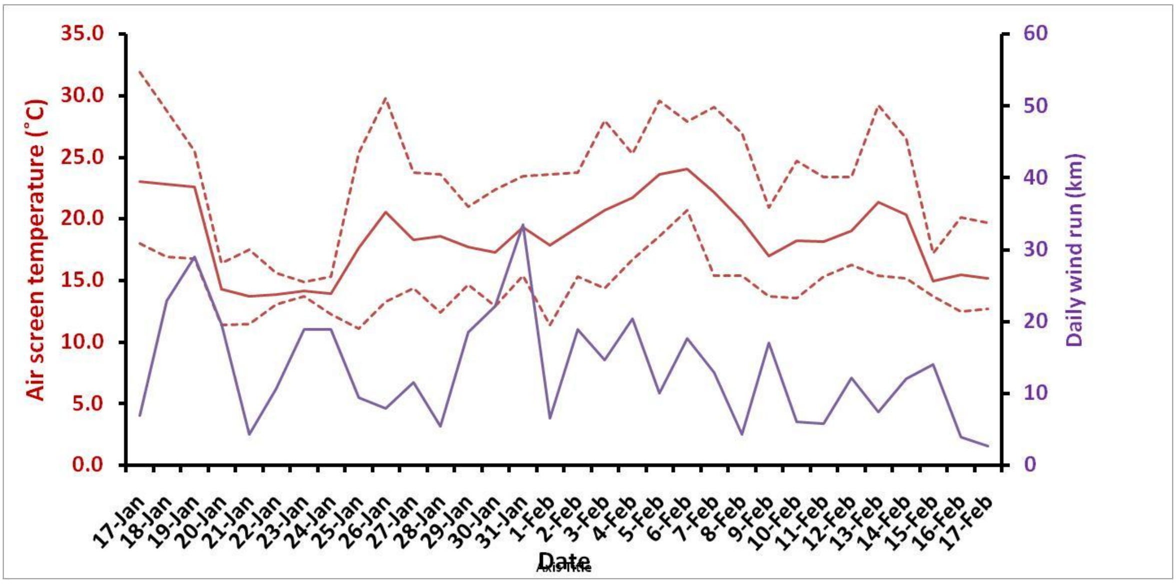

Figure 1. *Mean, maximum and minimum daily air screen temperatures and daily wind run recorded at the meteorological station at the bottom of the hill in the paddock Shade Rep1.*

Cow activities

All video records between 10 AM and 4 PM were viewed in the Rep 1 *Shade* paddock to determine when cows approached the dam or water trough. These data were expressed as a percentage of each hour when at least one cow was close to a water source (Fig.2).

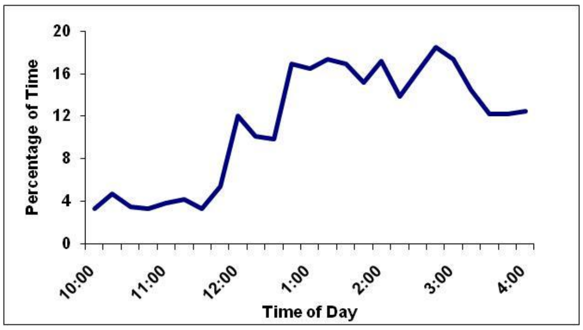

Figure 2. *Visual scoring of percentage of time spent by one or more cows close to either the water trough or the dam from mid-morning to mid- afternoon in one Shade paddock only.*

Compared to late morning, the *Shade* cows in Rep 1 spent considerably more time close to water during the afternoon. Many of these observations were in line with GPS tracking of when cows went for a drink, although many visits to water were not detected by GPS as it was in the off cycle for half of the daylight hours. This increased closeness to water corresponds with the rising daytime temperature but also follows the period of intense early morning eating that would have been contributing considerable amounts of metabolic heat when pasture wasw being digested (see rumen temperature data in Fig. 6). No comparative data from the other paddocks are available as the camera was too far from those paddocks and little time was spent videoing them.

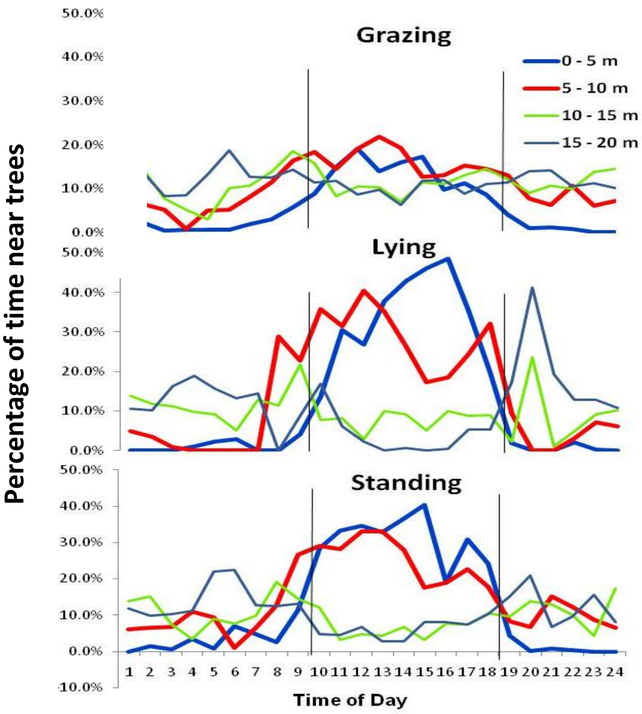

Figure 3. *Percentage of the (a) grazing, (b) lying, or (c) standing activity which occurred within 0-5, 5-10, 10-15 or 15-20 m of a tree compared to* <u>*that activity*</u> *which happened elsewhere in the paddock during that time. It is assumed that the cow was on the shady side of the tree. Vertical lines are references linking the figures.*

The standing, lying, or grazing activity within each hour as a percentage of the total of the respective activity across the whole paddock, that occurred near trees is shown in Fig.3. There was only a small increase in grazing by cows within 0-10 m of the tree between 9 AM and 7 PM, but this was unlikely to be much greater this small area of pasture would have been quickly consumed during the first couple of days. In contrast, from about 7 AM, if the cows were lying, 40% of this activity would have been within 5-10m from the tree, with 50% of the activity being even closer to the tree between 11 AM and 4 PM. A similar pattern of using shade was seen for standing.

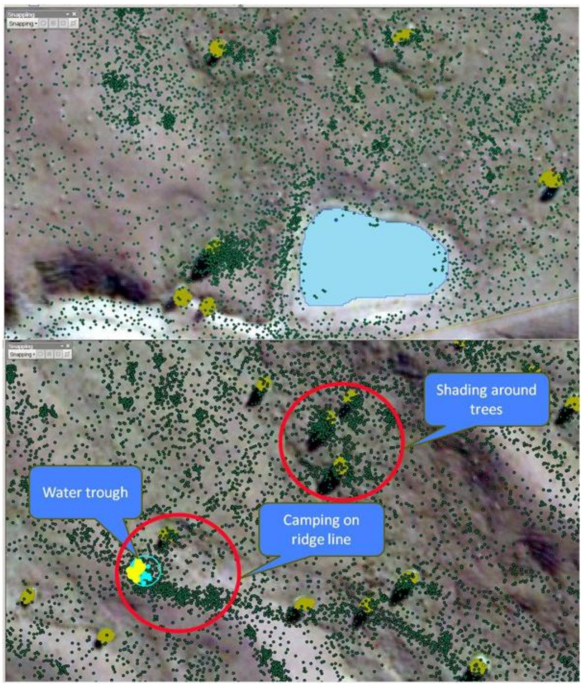

Figure 4. *GPS positions (◆) of cows set stocked within two areas of this one Shade paddock for 3 weeks. Positions were recorded for 20 minutes followed by 20 minute power down. Note clustering around trees, around and in the dam (top) and near the water trough and along ridges (bottom). Trees shadows are SW of the tree, indicating the aerial photograph was taken in the morning. Clustering of cows to the S and SE of trees is likely to occur during early afternoon*.

GIS layers (Fig 4) clearly show zones within one *Shade* paddock where cows congregated around trees, the dam, water trough and on ridges. These sites would receive a disproportionate amount of excreta compared to other areas of the paddock, as reported by Betteridge et al (2010a; Betteridge et al. 2010b). Those papers report that 50% of urination events were returned to between 6% and 10% of the paddock areas (i.e. campsites) in steep hill country. Such zones of excreta aggregation, whetehr due to long term stock camping or short-term summer shade, will become critical CSAs of phosphorous and faecal microbes should overland flowing water pass through them (McDowell 2012). Even without overland flow, such areas will leach significant amounts of nitrate or emit nitrous oxide to the air. While shade-providing trees may create CSAs, where they are spaced across the slopes of hill country pastures, these trees will attract cows away from stream banks and/or riparian zones. It has been shown in numerous studies that cattle spend more time around water in warm weather and particularly when no shade is available (e.g. Legrand et al. 2011, Schütz et al. 2010). This would reduce the potential for direct contamination of waterways while improving the spread of nutrients across the hills which typically suffer a negative nutrient balance due to livestock that graze on slopes but rest and excrete dung and urine in flatter areas (Gillingham & During 1973).

Grazing duration
Grazing was most dominant activity from around sunrise and in the three to four hours leading to sunset, with some grazing detected around 1 to 2 AM (Fig. 5). Grazing continued through the warmest time of the day but at much lower rates than at the beginning and end of the day. On days where the maximum ambient temperature exceeded 25˚C total grazing time showed *Shade* cows grazed 41 minutes (7%) longer per day than *No Shade* cows (Fig. 5). Similar findings have been demonstrated in NZ dairy cattle where cows spent more time grazing with increasing shade size (5 min/m^2 increase in shade size, Schütz et al., in preparation). This was most apparent between 2 and 5 PM and again between 7 and 9 PM. This complements findings that dairy cows with shade available increased their milk yield 0.5 kg/cow/day (Kendall et al. 2006) and confirms other research (Bryant et al. 2010). This 7% increase in grazing time which, if resulting in higher production, would be extremely valuable to the farmer. Our short term study was inappropriate for comparing liveweight change.

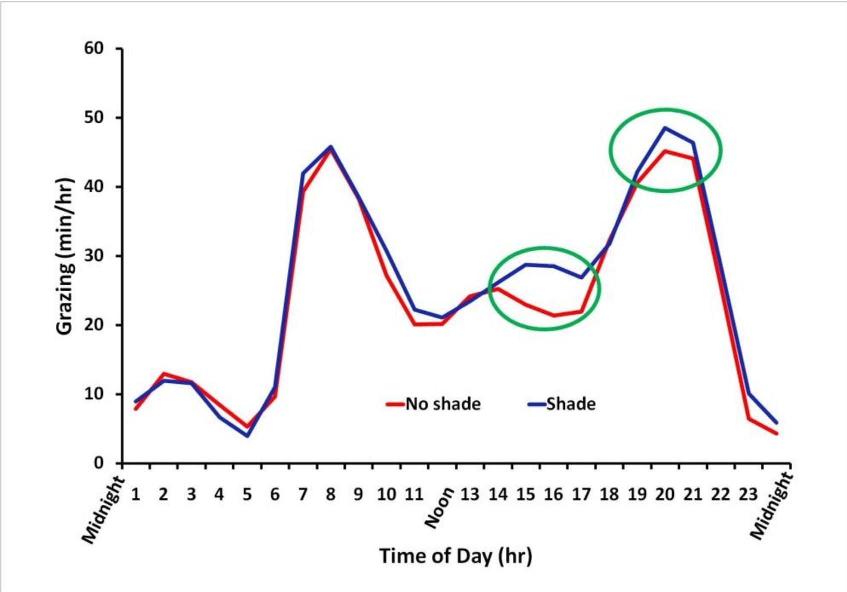

Figure 5. *Mean grazing activity throughout 24 hr by 6 Shade and 6 No shade cows during the 3-week trial, based on Icetag® motion activity records. Circles highlight periods when differences were greatest.*

Skin temperature
Over the three weeks, maximum ambient temperature in full sun averaged 36˚C compared to just 26˚C in the shade of the tree. Thus, cows had the potential to stand in an area that was some 10˚C cooler during the warmest time of each day. Given that the maximum temperature on the cows' back exceeded 50˚C on some days, it is clear that cows would likely use shade at least for some of the time between 10 AM and 4 PM. Figure 3 shows that cows offered shade did graze away from trees during some of this time, but while resting (standing or lying) they were clearly using the shade.

Skin temperature for the *Shade* cow in Fig.6 ranged between 20˚C and 51˚C during this one day. Measurement of temperature on the animal's back integrates insolation and ambient cooling, heat from rumen digestion and heat from the animal's metabolic processes. On this day it was near or above 30˚C from 5 PM until near midnight. With the peak at about 1 PM.

Rumen temperature

Rumen temperature, a close proxy for core body temperature, is affected by consumption of cool pasture and water. Although the average rumen temperature of the 8 cows with the rumen sensor was 39.2˚C, this fluctuated during the day (e.g. Fig. 6). We found that rumen temperature was a good indicator of the animal's drinking activity as rumen temperature dropped by 1-3˚C following a drink. Drinking often occurred once rumen temperature rose close to or above 40˚C, including at 1:30 AM for the cow shown in Fig. 6. Determination of drinking events was most easily identified when the rapidly fluctuating temperature data 'noise' (Fig. 7a) was statistically removed by first (Fig. 7b) and second derivative analyses (Fig. 7c) to emphasise the major changes in temperature, such as occurred when the cow drank water. The vertical red lines in Fig. 7 were applied to (a) where drinking was thought to have occurred. These same lines in (b) and (c) show that the temperature deviates occurring with drinking became increasingly clear (vertical blue lines in (c)) with nearly all 'noise' having been removed.

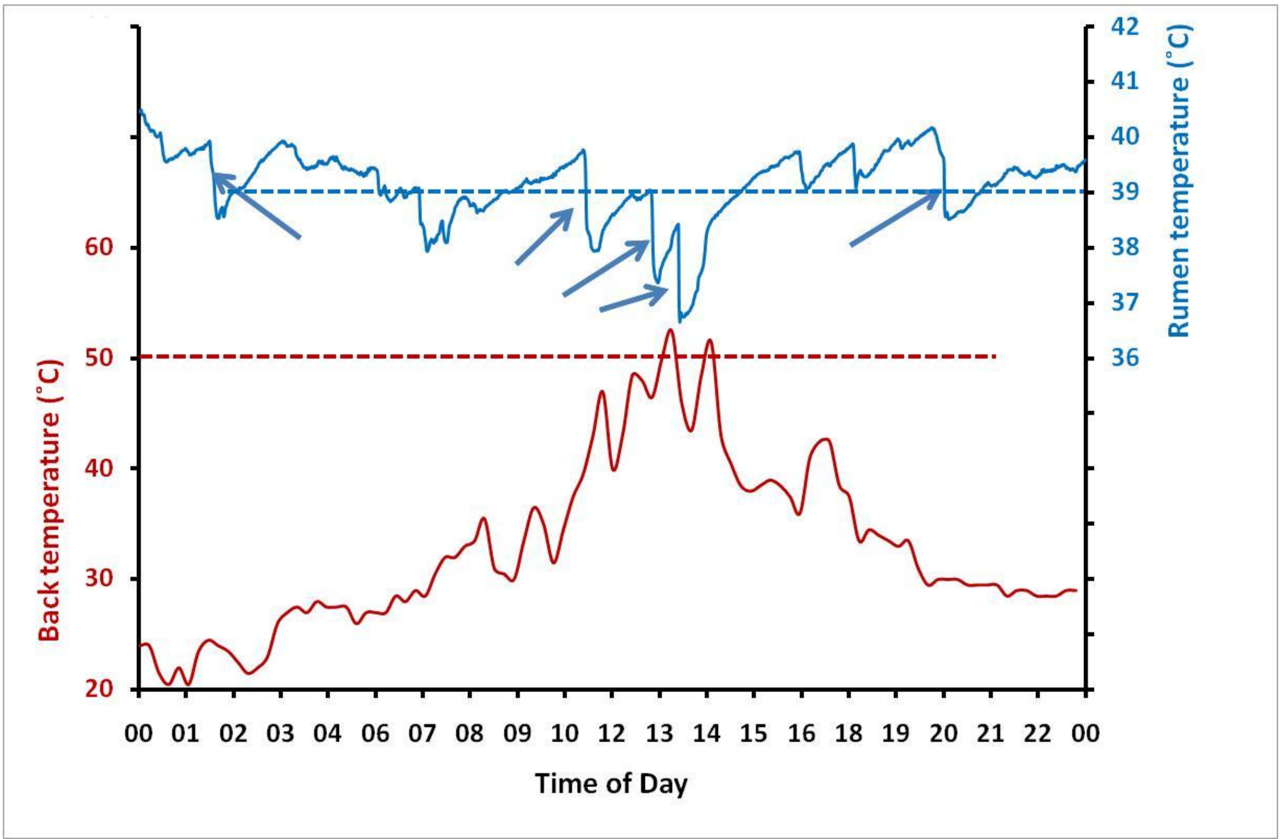

Figure 6. *Rumen temperature and dorsal skin(Back) temperature of one Shade cow to illustrate the independence of skin temperature and rumen temperature and the impact of drinking (arrows) on short-term rumen temperature change.*

Arrows in Fig. 6 indicate when the cow drank water, but the smaller sudden temperature drops may also have been due to drinking events but could have been caused by rumination that is known to shift the location of the rumen sensor within the rumen to a warmer or cooler zone (Pat Fernley, pers. comm.)

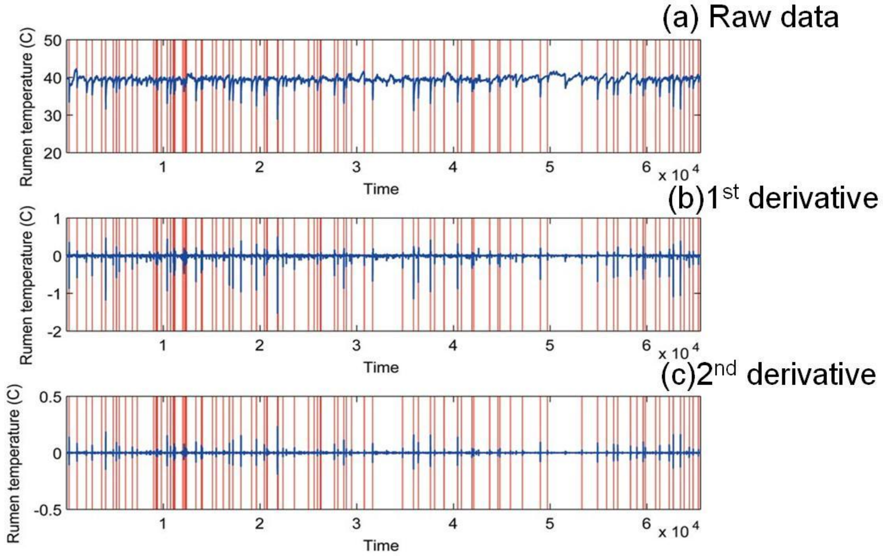

Figure 7. *Rumen temperature of one cow over the second and third week of the trial. Each red line represents our interpretation of a probable drinking event in the raw data. These lines have been repeated in the 1st and 2nd derivative analyses to show that 2nd derivative analyses of rumen temperature data offers a quick and simple technique for identifying drinking.*

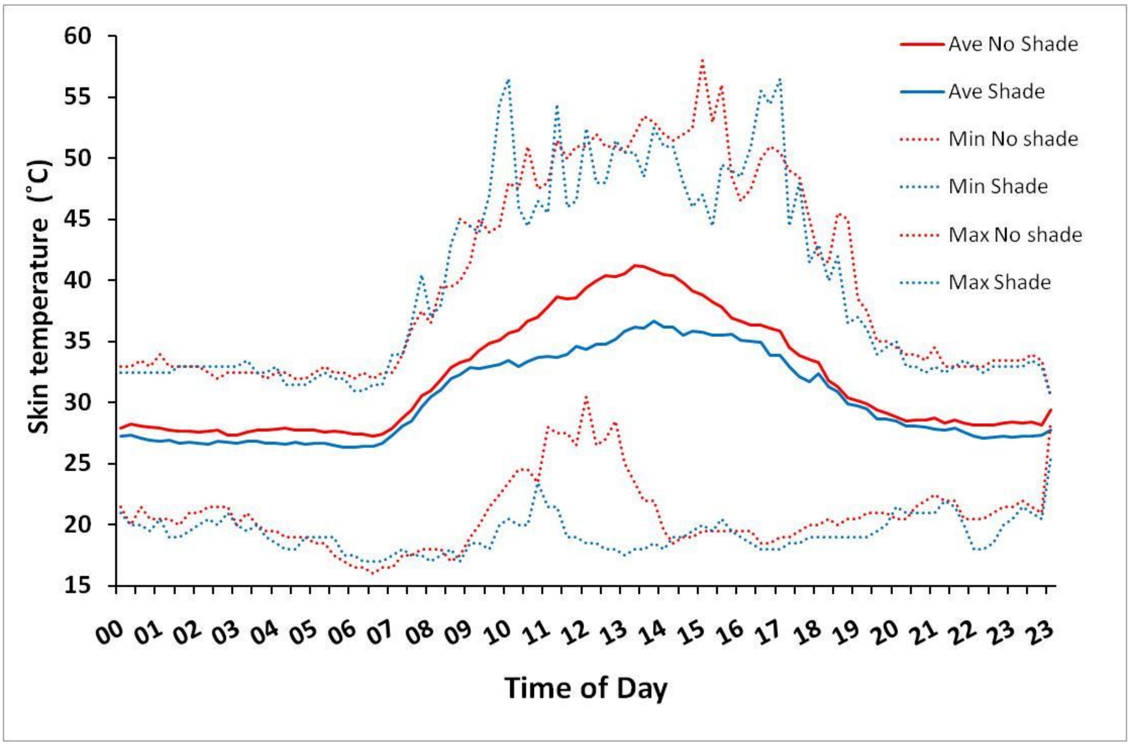

Figure 8. *Mean skin temperatures measured every 15 minutes over the 3-week trial period on the backs of cows with shade trees available (n=5) and without shade (n=4). Minimum and maximum values refer to the lowest and highest individual's values respectively, recorded within each 15-minute period across the trial period.*

Mean 3-week temperature on *No Shade* cows peaked at 41.1˚C compared to 36.7˚C on *Shade* cows with the divergence between the treatments starting at around 9 AM and convergence to a similar temeprature at around 6 PM (Fig.8). The similarly high maximum temperatures on the back of the *Shade* and *No shade* cows indicates that all *Shade* cows probably grazed in full sunlight at least some of the time during the hot afternoon periods, as shown in Figure 3 "Grazing" and in the video film. In contrast the lowest skin temperature values were 5-10˚C higher in the *No shade* cows between 11 AM and 2 PM,again supporting the observation that cows will, if possible, avail themselves of shade during the heat of the day. The rapid rise in rumen temperature from around 9 AM followed by the large drink at 11 AM (Figure 6), suggests that heat of fermentation following the early morning grazing bout from sunrise, caused this rise in rumen temperature even though the ambient temperature at that time of day was not high (data not shown). This rise in rumen temperature corresponds to the GPS and Icetag data (Figure 3) that show *Shade* cows started to stand or lye down close to shade trees from about 8 AM. This is much earlier than would be expected if solar heating was the main driving force for the cows to seek shade.

Creation of critical source areas

Because beef cows used shade trees in this summer dry hill country site both on hot and mild days, often from mid morning when temperatures were not hot, indicates that shade trees are likely to create potential CSAs of both nutrient and microbe enrichment (Betteridge et al. 2012). Pollution of larger waterways following overland flow events would be a concern to environmentally aware farmers if these trees, often planted for land stabilisation, were planted in gullies and around stream banks. However, on these two paddocks used for the *Shade* treatment, the willow trees were space planted around the paddocks, particularly in the steeper areas, and so the risk of overland flow would be less than if they had been in the gullies. Therefore, we contend that rather than creating more nutrient rich hotspots, space-planted trees led to cows having a much wider distribution across the steeper land with probably many more, smaller CSAs. Quite probably these would reverse the pattern where nutrients that are applied as fertiliser to hill slopes are transported to the ridge tops and valley floors (Saggar et al. 1988; Rowarth et al. 1992). Also, as the sun moves across the sky, so does the effective shade move across the paddock and thus the spread of excreta will be further enhanced except perhaps at the hottest period of the day when the cows are closest to the tree trunk (0-5 m, Fig.3). Any additional nutrient returned to the slopes reduces that returned to the already highly fertile valley floors and thereby reduces the considerably higher risk of stream pollution.

Should trees be space-planted on hill country pastures, selection of the most appropriate species for shade and soil stabilisation the site is important and help with this can be obtained from Regional Councils or in the literature (Charlton et al. 2007). Such trees will stabilise steep soils, potentially provide forage in droughts, improve animal welfare by offering shade and increase grazing time in hot weather. Trials are needed to show that this additional grazing culminates in improved animal performance. Similar trials with sheep are also needed as some farmers say that sheep use shade more readily than do cattle. The heat stress that our cows experienced was probably more than cows with lighter coloured coats would experience. However, as our cows used shade trees early in the day, coat colour may be of relatively minor importance to the heat distress the animals experienced at that time.

Acknowledgements

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