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Prepared by: Nigel Tomkins & Ed Charmley
CSIRO Livestock Industries

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Quantifying and predicting patch selection by cattle under different management strategies

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Abstract

This project used Global positioning systems (GPS) and geographic information systems (GIS) to understand grazing animal distribution at two paddock scales. Research was conducted in experimental paddocks (~100 ha) at Wambiana Station and in a 1500 ha paddock at Trafalgar Station, both near Charters Towers. Factors significantly influencing animal distribution were land-type, based on soil and dominant vegetation, and proximity to water. Daily patterns of distance travelled by grazing animals were similar in experimental and commercial sized paddocks. Specific forage use or an absolute measure of grazing activity was not determined in this project. However, periods likely to be associated with grazing, resting/ruminating or moving were indirectly identified and spatially aligned with broad soil groups to calculate preference indices.

Spatial variation in animal position within a paddock may be more critical than overall stocking density in determining over- or under-utilization of heterogeneous pastures. Although some commonalities in animal distribution between study sites were apparent, it was not possible to extrapolate from experimental to commercial scales. The GPS technology was still in the developmental phase and the extreme conditions encountered in this trial were a challenge for the hardware. Results were compromised by both the functionality of equipment and poor pasture growth at Wambiana. Nevertheless, the data has contributed to the knowledge base of grazing management for heterogeneous pastures in the sub tropical savannas of northern Queensland.

Executive summary

Optimizing pasture utilization rate is crucial for both cattle and pasture productivity. Marked seasonal rainfall supports a wide range of grasses, legumes and forbs that, in association with mixed soil types, contribute to marked heterogeneity in grazing systems. Selective grazing in heterogeneous environments is inevitable and leads to uneven utilization of available herbage. Management can alleviate landscape selection and patch grazing to an extent. However, there is little information on how to balance grazing pressure and landscape selection. With the commercial development of global positioning system (GPS) for tracking animals it is now possible to monitor animal distribution across the landscape and obtain and indication of land-type selection.

This project was conducted to quantify the influence of the environmental factors on grazing animal distribution across variable land-types using GPS derived animal positional data. Although the Wambiana study site was atypical of most northern Australian grazing situations in terms of size and shape of paddocks, it allowed for intensive measurement of landscape attributes in a replicated design. The commercial site was chosen to be more representative of commercial properties, but lacked the richness of data and replication.

Four separate, but inter-related components of the project targeted the following objectives, to:

1. Quantify the impact of utilisation rate on patch and landscape selection by cattle at Wambiana Station under experimental conditions.
2. Identify the major biophysical determinants driving patch and land-type selection at the Wambiana field site.
3. Construct empirical relationships that relate patch and land-type selection by grazing cattle to soil and vegetation characteristics for the Wambiana site and test these in a large, commercial paddock.
4. Develop preliminary management guidelines that will enable graziers to manage large, spatially heterogeneous paddocks in a sustainable and productive manner.

To satisfy objectives 1 and 2, four deployments of GPS units on cattle were conducted over three consecutive wet/dry seasons as part of a long term stocking rate trial. Paddocks ranging in size from 92 to 115 ha were initially fenced to encompass an even distribution of three distinct soil groups. Each paddock was considered to be representative of the surrounding area and 11 distinct soil-vegetation associations were identified across the study site for the purposes of defining land-types. The spatial data collected was used to determine occupancy rate of collared animals per land-type, but could not be directly used to explicitly differentiate between specific animal behaviour such as walking, resting/ruminating and grazing. It was not possible to relate an absolute measure of animal behaviour to specific land-types without field observations. Temporally, it was demonstrated that cattle walk in excess of 8 km per day. Animal movement, based on distances travelled per hour, indicated clear diurnal patterns. Peak activity, related to grazing, occurred around dawn and dusk and preferentially in land-types associated with clay soils. However, spatial movement of cattle under experimental conditions was predominantly influenced by the small size of paddocks and drought conditions. These conditions were also thought to contribute to the absence of well defined patches across the experimental paddocks resulting in insufficient data to measure specific patch selection within each of the land-types identified at the Wambiana study site. Nevertheless, a hierarchy of drivers for animal movement has been suggested.

To satisfy objectives 3 and 4 the data were analysed in terms of both temporal and spatial behaviour. To determine the spatial distribution of individual animals, a grid pattern, centred on a

known reference point and based on 25 x 25 m cells, was applied across each study site. This approach used occupancy, or positional data, and proportion of land-type available to determine selection ratios for individual animals. A conditional model, based on resource selection functions (RSF; Boyce *et al.* 2002) was used to describe the animal-landscape associations. This approach combined a model to accommodate the binary (presence/absence) nature of the data; and then a second distribution, conditional upon their presence. Land-types, based on soil vegetation associations influenced animal distribution at both the experimental and commercial scale. Since these associations are often site specific, it was not possible to extrapolate relationships from one site to another. In particular, at the Wambiana study site, all land-types were grazed because of limiting biomass availability and this did not facilitate the development of robust empirical relationships relating grazing to specific soil and vegetation characteristics. At both the experimental and commercial scales, the watering points were highly frequented areas of the paddock and clearly influenced the relationships between cattle and other environmental factors.

The results from the project were unique for each study site and are preliminary in nature for developing grazing management guidelines suitable to large, heterogeneous paddocks. The technology is still in the developmental phase and the extreme conditions encountered in this trial were a challenge for the hardware. Only with increased data acquisition can predictive models of land-type selection and ultimately patch grazing in heterogeneous environments become a reality. Such models will be of direct relevance to graziers as they adapt best management practices for both production and sustainability outcomes. The use of models to predict grazing dynamics, and the likelihood of overgrazing or under-grazing particular land-types, will be a specific tool to assist industry maintain and/or improve land condition while achieving economically sustainable stocking rates.

The results obtained from this project are based on a very limited dataset. However, the lessons learned from the Wambiana and commercial deployments will be invaluable for conducting future work of a similar nature. Within five years it would not be unrealistic to expect that similar studies would be conducted on a larger scale to compliment a suite of land-types typical of the tropical savannas.

Contents

1. Background

The extensive grazing systems of northern Australia support a beef industry worth $1.5 billion to the Australian economy (ABARE 2006). Poor soils and marked seasonal rainfall support a wide range of native and introduced grasses, legumes and forbs. This range of pasture communities, in association with mixed soil types, contributes to marked heterogeneity in unimproved and improved grazing systems. Heterogeneous pastures are inherently difficult to manage due to marked seasonal growth and selection by livestock for palatable pasture species (O'Reagain and Turner 1992). Optimizing pasture utilization rate, on a paddock-scale basis, is crucial for both cattle (conception rate, branding rate and live weight gain) and pasture productivity (ground cover, land condition, species composition). However, patch grazing in heterogenous paddocks is inevitable and consequently some areas are over-grazed while other areas are under-grazed (O'Reagain 2001). This can result in loss of perennial species, excessive bare ground and poor regrowth after rains in overgrazed areas. Conversely, under-grazed areas become rank and unattractive to cattle.

Management can alleviate landscape selection and patch grazing to an extent. Fencing to land-type and strategic placement of watering points, seasonal spelling and fire can be incorporated in property management. However, these interventions can be expensive and there is little information on how to maximize the effectiveness of such practices to manage landscape selection. This lack of understanding can be partly attributed to the difficulty in monitoring landscape selection by free ranging animals. Indirect methods of measuring selection by botanical assessment are labour intensive and impractical in extensive grazing systems. Direct observations of animal grazing is tedious, time consuming and possibly biased by the effects of human observers on grazing behaviour.

It is only since the commercial development of global positioning system (GPS) that a relatively reliable and easy method to monitor landscape selection by grazing animals has emerged (Rodgers 2001). Combining GPS cattle positional data with geographic information systems (GIS) is becoming more common in studying pasture-animal interactions, particularly in extensive landscapes. GPS data on animal movement can be integrated with GIS overlays for topography, vegetation, soil type and other landscape features. Information can then be used in modelling grazing behaviour within spatially heterogenous landscapes (Wade *et al*. 1998; Parsons *et al.* 2001). This technology requires rigorous testing under northern Australian conditions before it can benefit the industry.

2. Project objectives

This report details the findings of a project conducted to quantify the distribution of grazing cattle using GPS and GIS technologies. Four deployments of GPS units were conducted at Wambiana Station and one in a commercial paddock, Trafalgar Station, near Charters Towers with the following objectives;

- Quantify the impact of utilisation rate on patch and landscape selection by cattle at Wambiana.
- Identify the major biophysical determinants driving patch and land-type selection at the Wambiana field site.
- Construct robust empirical relationships that relate patch and land-type selection by grazing cattle to soil and vegetation characteristics for the Wambiana site and test these relationships in a large commercial paddock.

- Develop preliminary management guidelines to enable graziers to manage large, spatially heterogeneous paddocks in a sustainable and productive manner (basic guidelines will be provided, but not a computer based decision support system).

3. Methodology

3.1 Wambiana site

3.1.1 Study location

The study was conducted in association with the larger project "Coping with rainfall variability; Grazing management strategies for the seasonably variable tropical savannas" at Wambiana Station (20°34'S 146°07'E). The study area included four experimental paddocks, each approximately 100 ha. The landscape was dominated by Eastern sub-humid woodlands comprising of *Eucalyptus spp.* (Northern box and Ironbark), over a sparse shrub layer with a sward dominated by *Aristida spp*. and tussock C_4 tropical grasses on undulating low hills. Dominant soils were unfertile and derived from tertiary sediments, brown and fine textured with bleached sand to sandy clay loams over clay subsoils or red or yellow massive earths. Total rainfall, from October 2004 to October 2005 averaged for seven different sites over the study area, was 617 ± 15.3 mm. Approximately 40% of this occurred in the months of January and February.

3.1.2 Site description

Paddocks were initially fenced to encompass an even distribution of three distinct soil types and ranged in size from 92 to 115 ha. Each paddock was considered to be representative of the surrounding area. Two water points were located 1200 to 1700 m apart in each paddock. The water points were located on a fence line and serviced adjacent non-experimental paddocks (Figure 3.1).

The three major soil/vegetation classifications and their percentage of total paddock area were; *a*) *E. melanophloia* (Silver-leaved ironbark) community on yellow/red kandosols (23%), *b*) *Acacia harpophylla* (Brigalow) community on grey vertosols (22%) and *c*) *E. brownii* (Box) community on brown sodosols and chromosols (55%); (O'Reagain and Bushell 2003). These main types were sub-divided into 11 different soil/vegetation associations for the purposes of this project (Table 3.1).

Intensive, spatially explicit vegetation and soil measurements were collected as part of the larger project "Coping with rainfall variability; grazing management strategies for the seasonably variable tropical savannas". These data included, detailed soil/vegetation associations, broad soil groups and soil N, P and K concentrations. Pasture yield (kg DM/ha) and ground cover (%) was determined using BOTANAL methodology (Tothill *et al.* 1992) in April 2004/05 and October 2004/05 along fixed transects that bisected each experimental paddock. Mean values were used to characterise each land-type. Landsat satellite imagery was used to calculate a Normalised Difference Vegetation Index (NDVI; Townshend 1994) across each experimental paddock. Data from the Statewide Landcover and Trees Study (SLATS, 2004) project was used to provide information on woody vegetation cover throughout the project. The term tree cover is used to describe this data set. A 25 x 25 m grid, based on the SLATS dataset, was imposed on each experimental paddock used in this study. Together with identifying x, y co-ordinates and centroid, a unique set of characteristics, based on soil and vegetation data were identified for each cell to establish spatial attributes across each paddock. In each cell, the presence or absence of a fence line or water point was indicated as 1 or 0, respectively.

3.1.3 Animals, management and GPS data sampling

Mixed age Brahman cross steers (range 246 to 399 kg) were allocated to two heavy stocking rate paddocks (4 ha / adult steer) and two light stocking rate paddocks (8 ha / adult steer) in October 2004. Half the steers were replaced each year with 18 month old cattle. Animals were continuously supplied with a urea based dry mineral supplement (Phos Wet Season Custom stock supplement, Stocklick Trading Qld. 21.7% urea equivalent) per paddock. In addition, a Molasses-8 % urea supplement was made available, on an intermittent basis, in each heavily stocked paddock.

The project consisted of four deployments of archival GPS units (BlueSky Telemetry Ltd, Scotland) on free ranging cattle, two in the dry season (October 2004 and 2005) and two in the wet season (February 2005 and 2006). Twelve animals in total (3 per paddock) were fitted with GPS units for four to six weeks (Figure 3.2) for each deployment. Positional data (longitude and latitude) for cattle were collected every 60 minutes for deployments 1 and 2 and every 30 minutes for deployments 3 and 4 for up to 300 s from a minimum of four satellites. Maximum horizontal positional error was set at 10m to ensure that the resolution of the positional data collected was within the grid size used across all experimental paddocks. Additional data fields recorded by the GPS units were: status, horizontal and vertical error, height, temperature, pitch and roll (Table A9.1.1).

3.2 Trafalgar station

3.2.1 Study location

The commercial paddock was located on Trafalgar Station (20º30’S, 145º58’E) 60 km SW of Charters Towers. Total annual rainfall for the property in 2005 was 619 mm. Conditions were initially dry, but from October 2005 to January 2006 scattered falls of rain totalled 90 mm and ensured good pasture growth. Soils were predominantly Phosphorus deficient yellow earths. Brown cracking clays and texture contrast soils were also present.

3.2.2 Site description

The study site was a 1530 ha paddock that contained a single water point located in the extreme southwest corner of the paddock (Figure 3.3). The study site contained a very diverse mixture of land-types (Table 3.2) and three large hills with steep stony slopes dominated the NE corner. Four major soil/vegetation association were identified; *a*) a large area of relatively flat, cleared *Acacia argyrodendron* (Blackwood) dominated by *Cenchrus cilliaris* (Buffel grass) on texture contrast and clay soils, *b*) remnant uncleared Blackwood woodland containing native grasses and some Buffel, *c*) predominant *E. melanophloia* (Silver-leaved Ironbark) and native grasses on texture contrast soils, and *d*) stony slopes dominated by *A. shirleyi* (Lancewood) scrub and *Spinifex* and Eriachne *spp*. (Wanderie grass).

Spatially explicit vegetation and soil measurements for the study site were collected. These data included soil/vegetation associations and broad soil groups. Paddock surveys and Landsat satellite imagery were used to map dominant vegetation types. Pasture yield and composition was determined using BOTANAL methodology (Tothill *et al*. 1992) along six, 3-4 km transects that bisected all vegetation types; operators used motorbikes and assessed pasture yield at 50 m intervals for visually estimated quadrats of approximately 4 m^2. Visual estimates of pasture yield were calibrated against clipped yields for each operator.

Conditions were initially dry during the study period, but scattered falls of rain through December and January (total rainfall: 121 mm) ensured good pasture growth. Temperatures were generally hot over the study period with maximum daily temperatures commonly in excess of 36 ºC.

3.2.3 Animals, management and GPS data sampling

A herd of approximately 180 Brahman cows with calves were allocated to the previously spelled paddock. Twelve cows were randomly selected during a routine muster and each animal fitted with a GPS unit (Figure 3.2) for eight weeks (24 November 2005 to 16 January 2006). Collars were programmed to obtain a position every 30 min for up to 300 s from a minimum of four satellites. Maximum acceptable value for horizontal position error was set at 10 m.

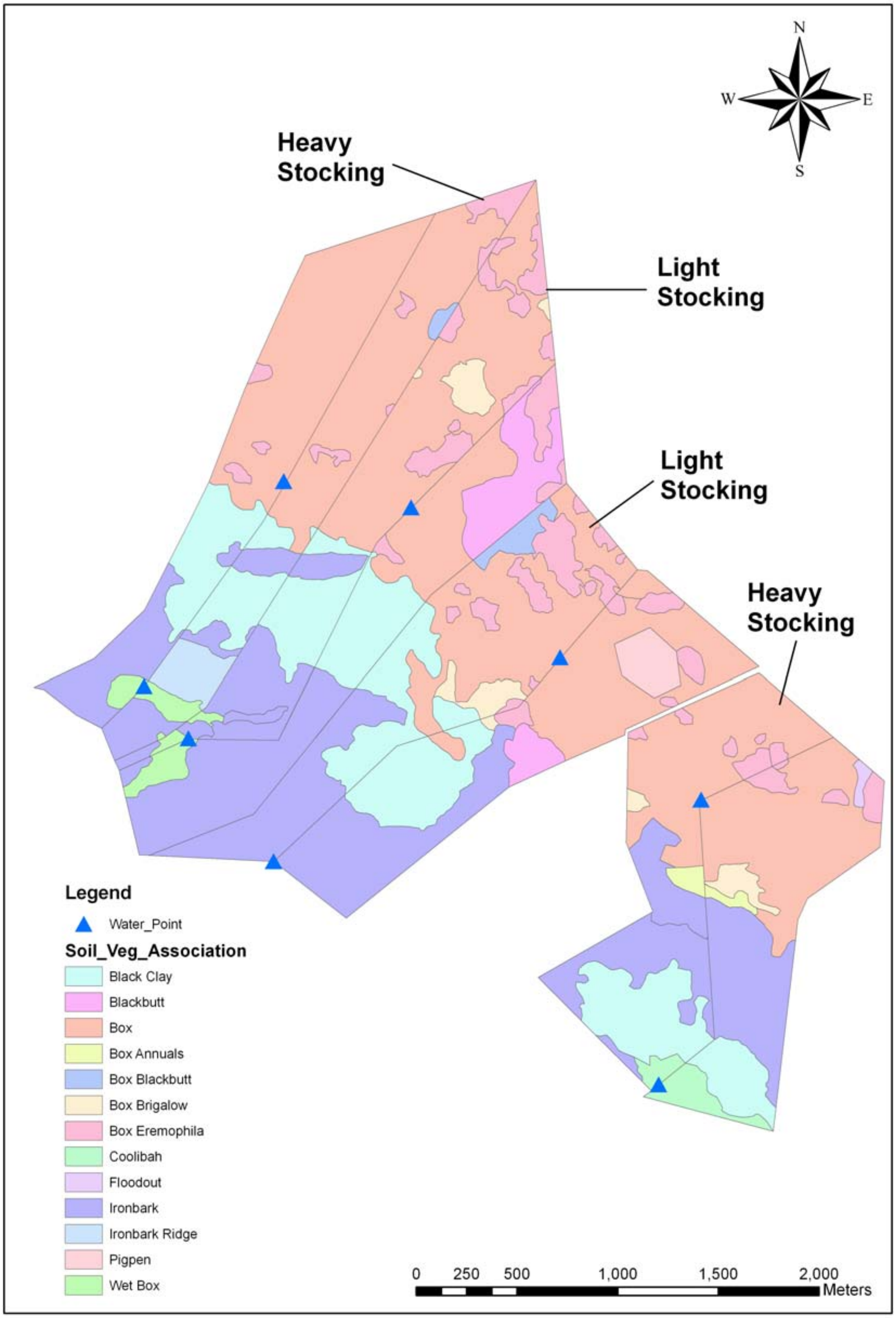

Figure 3.1 Site map and land-types across Wambiana based on soil-vegetation association

a

b

c

Figure 3.2. GPS units fitted to grazing cattle. a) Detail of unit on animal, b) units on Brahman cross steers, Wambiana and c) on Brahman cows in a commercial sized paddock

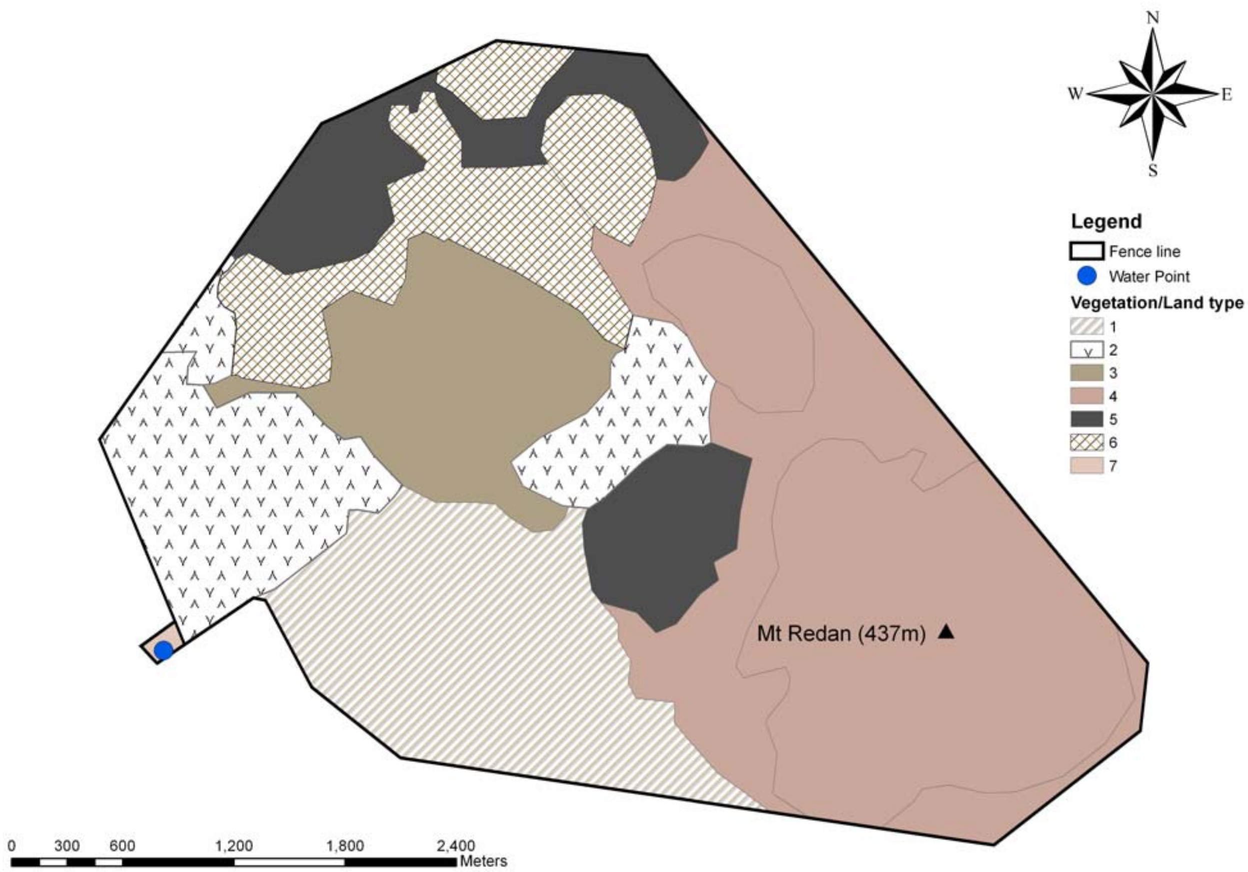

Figure 3.3 Site map and land-type across a commercial sized paddock, Trafalgar Station. Land-types were based on soil-vegetation associations; *1*) Cleared Blackwood (*A. argyrodendron)* woodland on heavy clay and duplex soils, *2*) Intact Blackwood woodland on heavy clays and duplex soils, *3*) Open Box (*E. brownie*) woodland on texture contrast soils with Narrow-leaved red ironbark (*E. crebra)* in places, *4*) Silver-leaved ironbark (*E. melanophloia*) with *Acacia spp*. and some Narrow-leaved red ironbark on shallow texture contrast soils, *5*) Narrow-leaved red ironbark on red soil, *6*) Silver-leaved ironbark with some Lancewood (*E. shirleyi*) and wattle thickets on stony shallow soils, *7*) Fenced area < 1ha, subset of (*1*).

Table 3.1 Vegetation type, soil classification, description, pasture production, pasture species associated with each vegetation site and grazing preference estimates for the Wambiana study site (O'Reagain *pers comm*. 2006).

Vegetation type	Broad soil group	Classification	Common term	Description	Pasture production (kg/ha)	Grazing preference	Pasture species
Coolibah	Heavy clay	Grey sodosol/dermosol	Coolibah	Open Coolibah on heavy clays, seasonal waterlogging	High > 2000	Moderate, avoided when rank	*Dicanthium sericeum & Bothriochloa ewartiana*
Black Clay	Heavy clay	Grey vertosol	Brigalow	Brigalow or Box on heavy clay soils, can get wet	High > 2000	Moderate, avoided when rank	*D. sericeum, Eulalia aurea, B. ewartiana*
Ironbark	Yellow earth	Yellow/brown kandosol	Ironbark	Silver leaf Ironbark	Low < 1500	Low to variable	*Aristida spp., Annuals, Heteropogon contortus*
Box annuals	Duplex - shallow	Grey/black sodosol	Sodic box	Box with Sedge and Chloris lawns	V low <1000	Low-moderate	*Sedges, Chloris spp., Chrysopogon fallax*
Box Brigalow	Heavy clay	Grey vertosol/sodosol	Sodic box	Box & Brigalow on heavier duplex/clay soils	High > 2000	Moderate	*B. ewartiana & C. fallax*
Box Eremophila	Duplex	Brown sodosol-yellow kandosol	Box	Box with understorey of Eremophila	Med > 1500	Moderate	*B. ewartiana & C. fallax*
Wet box	Heavy clay	Grey earth	Open flooded box	Box, subject to water logging	Med > 1500	Low-moderate	*B. ewartiana, sedges etc*
Box	Duplex	Brown/grey sodosol	Box	Box woodland	Med > 1500	Moderate	*B. ewartiana & C. fallax*
Blackbutt	Duplex	Grey sodosol	Blackbutt	Blackbbutt on shallow sodosols	Low-Med > 1500	High	*Enteropogon & Chloris spp.*
Ironbark Ridge	Yellow/ Red earth	Yellow/brown kandosol	Ironbark	Silver leaf Ironbark on Eriachne ridges	Low < 1500	Low	*Eriachne*
Box Blackbutt	Dupex-heavy clay	Grey/black sodosol	Blackbutt/box	Box/black butt on sodosols	Med > 1500	Moderate	*B. ewartiana & C. fallax*

Table 3.2 Land-type and description of dominant vegetation types for the commercial paddock, Trafalgar Station

No.	Name	Description
1	Cleared pastures	Cleared Blackwood *Acacia argyrodendron* woodland on heavy clays and duplex soils. Over sown with *Cenchrus cilliaris* (Buffel grass), but having good native pastures in small areas. Some bare patches also present
2	Blackwood woodland	Intact Blackwood woodland on heavy clays and duplex soils, some on stony shallow soils. Sparse, but palatable native grasses
3	Box woodland	Open Box (*Eucalyptus brownii*) woodland on texture contrast soils, with *E. crebra* in places, better native grasses (*Bothriochloa ewartiana)* in more productive patches
4	Silver-leaved Ironbark	Silver-leaved Ironbark (*E. melanophloia*) with wattle (*Acacia spp*.) and some *E. crebra* on shallow texture contrast soils. Very sparse native grasses. Substantial areas of bare ground
5	Narrow leaved Ironbark	*E. crebra* on better red soils. Severe scalding in places, sparse native grasses
6	Shallow stony slopes	Silver-leaved Ironbark (*E. melanophloia)* with some lancewood (*E. shirleyi*) and wattle thickets, on stony shallow soils. Very sparse *Eriachne* grasses in thicker scrub, *Spinifex* tussocks with *E. crebra* on very stony open slopes
7	Water point	Fenced area <1 ha, freely accessible to stock, subset of (1)

3.3 Data processing

3.3.1. Wambiana site

Details relating to data collection and processing are given in Table A9.1.2. Individual animal position data was retrieved from the GPS collars at the end of each deployment using a wireless interface and downloaded onto a laptop computer. Positional data were converted from latitude and longitude to Eastings/Northings to facilitate algebraic calculations using EXCEL™ (Microsoft 2003) for distances travelled, or distance to individual water points.

Temporal and spatial relationships were derived from individual data sets and mean values are presented. Initially, each individual animal data set was scanned to identify 24 h periods where there was a continuous record of GPS positions. This criterion was used because straight-line paths between consecutive points were assumed when calculating distances. These data were then used to determine distances travelled over a 24 h period, diurnal patterns of animal movement and distances from water points. Periods of high or low activity, assumed to be grazing, or resting and ruminating, respectively, were identified based on distances travelled per hour. When animals travelled between 250 and 500 m per hour this was assumed to be indicative of periods of high activity, namely grazing. Periods of low activity were associated with distances of less than 250 m travelled per hour and interpreted as resting or ruminating.

Individual distances travelled by animals were log-transformed for statistical analysis to satisfy normality assumptions.

To determine the spatial distribution of individual animals, a grid pattern, centred on a known reference point and based on 25 x 25 m cells, was applied across the Wambiana study site. This approach used a presence or absence (1 or 0, respectively) criterion to indicate the location of an animal for each cell. Spatial behavioural analysis for individual animals used all available GPS positional data.

In order to determine the proportion of land-types frequented by animals, spatial analyst and data management tools in ArcMap™9.1 (ESRI, Aust) were used. Point density values, based on individual animal x,y coordinates, for soil and land-type polygons were determined. When an animal frequented a cell more than once, the frequency or sum of visits was calculated for each cell.

Minimum convex polygons (MCP), capturing 95 % of positional data per animal, were also calculated using ArcMap™ 9.1 (ESRI, Aust).

Spatial biophysical determinants, based on independent landscape variables; vegetation, pasture and soil type, were obtained by soil and pasture surveys and from independent GIS layers. For the purposes of this study, 11 determinants were associated with each 25 x 25 m cell. Data was spatially captured, transposed into the mapping software, using data management and conversion tools and extracted into ASCII files using conversion tools in ArcMap™ 9.1 (ESRI, Aust). The final extraction into EXCEL™ (Microsoft, 2003) was limited to the output extents of reference points and the 25 x 25 m grid pattern. Once in ASCII format, the data was transposed into rows and columns of a matrix that captured the environmental heterogeneity and animal point density data for each paddock.

Biophysical determinants were grouped according to; i) tree cover (SLATS 2004), ii) pasture characteristics [pasture yield (kg/ha), ground cover (%), NDVI] and iii) soil and dominant vegetation type [soil type, nutrient status (N, P, K mg/kg), soil/vegetation land-types].

The physical determinants were limited to the location of water points and fence lines. These were designated as present or absent (1 or 0, respectively) for each 25 x 25 m cell.

Preference and standardised indices (Hobbs and Bowden 1982; Manly *et al*. 1972) were calculated for each land-type and each of the major soil groups (clay, duplex, red/yellow earths) using animal positional data.

3.4.2. Trafalgar station

In the commercial paddock deployment there were no treatments, paddock replication or repeated measures in time. Twelve cows were randomly selected for GPS tracking from a herd of approximately 180 breeder cows with calves.

Temporal data relating to MCP values, for all animals for the duration of the deployment, and individual distances travelled over 24 h were calculated as for the Wambiana study.

MCP values were also determined 7, 14 and 21 days after collared cattle entered the paddock. Allometric rescaling (Schneider 1994) for MCP and distances travelled by animals was used to determine the similarity between spatial relationships in small paddocks at Wambiana to the larger commercial paddock.

Preference and standardised indices (Hobbs and Bowden 1982; Manly *et al*. 1972) were calculated for each land-type using animal positional data.

3.4 Statistical analysis

3.4.1. Wambiana site

For the purposes of this study, the design was a 2 x 2 factorial with treatment (light and heavy stocking) and paddock as the factors, with three repeated measures (deployments) over time. The quantity of data from the fourth deployment was insufficient to be used in the statistical analysis.

The experimental unit for the Wambiana study was the individual collared animal and the association with resources measured for each. Availability of a resource was measured at the population, or herd, level.

To overcome the unbalanced nature of the locational data, the data relating to temporal behaviour of individual animals were analysed using the method of residual maximum likelihood (REML) in GenStat® (V8.2, 2005). Stocking rate effects were tested using a Wald test. Pair-wise comparisons of the means were made using a least significant difference test.

Preliminary statistical analysis revealed no effects of wet versus dry season. This factor was removed from the analysis.

A conditional model, based on resource selection functions (RSF; Boyce *et al.* 2002) was used to describe the animal-landscape associations. This approach combined a model to accommodate the binary (presence/absence) nature of the zeros in the data; and then a second distribution, Poisson with a Log-link function, conditional upon their presence. It was assumed that all continuous variables (tree cover, NDVI, pasture yield and ground cover) had linear relationships. These generalised linear models were used to evaluate the probability of animal-landscape associations and were parameterised by a reference level selected in the model.

4. Results and discussion

This section is arranged according to the objectives of the project (4.1 to 4.3) followed by a section on findings additional to these objectives (4.4). A section on technical difficulties and lessons learned is included (4.5).

Interpretation of animal positional data to determine landscape selection was based on the occupancy (presence or absence) of cattle in 25 x 25 m cells applied across both the Wambiana and commercial paddock study sites. Consequently, at this scale, the positional data could only be used as a basis to determine measures of land-type selection rather than specific patch selection within defined land-types.

Although the GPS units collected minimum and maximum pitch and roll values during each deployment, the integrity of the data was not sufficient for disaggregating animal activity into resting, grazing or walking components. This project could not explicitly associate animal positional data with behaviour such as grazing to determine forage use based on land-type. Nevertheless, analysis of all the positional data, based on hourly distances travelled, indicated a crepuscular pattern of livestock movement. This relationship was used to differentiate between assumed periods of grazing and resting/walking, based on animal behavioural observations recorded in similar environments.

4.1 The impacts of utilisation rate on patch and landscape selection by cattle at Wambiana.

The original intent of the project was to assess the effects of stocking or utilization rate (light versus heavy) on patch and landscape selection. Stocking rate throughout the two years of the study had an obvious effect on biomass availability as seen in the IKONOS image (Figure 4.1). However, the frequency and extent of pasture yield estimates and composition could not be correlated with animal positional data and related to specific defoliation of patches within each experimental paddock or land-type.

Average DM yield data are presented in Tables 4.1 and 4.2 for comparison. However, no effects from stocking (utilization) rate were observed for landscape or patch selection in the experimental paddocks at Wambiana. This was attributed to the size, elongated shape of paddocks and the influence of water and supplement points. Throughout the study period the use of molasses based supplementation (M8U) varied. In addition, when it became apparent that wet seasons were below average, the high stocking rate treatment was changed from 4 ha / beast in deployments 1 and 2, to approximately 6.2 ha / beast in deployment 3. The mean (± sem) initial live weight of cattle for each deployment was 304 ± 4.8 kg, 307 ± 4.1 kg and 410 ± 5.8 kg, respectively. Nevertheless, the data from Wambiana did reveal patterns of landscape use at both stocking rates. This is discussed in further detail in section 4.2.

4.2 Biophysical determinants driving patch and land-type selection at Wambiana

Land-type animal associations are primarily determined by the quality and availability of forage and animals typically select areas offering the greatest intake rate of digestible energy. Such associations are conditional upon the animal's metabolic requirements and other factors such as accessibility and protection from the elements (O'Reagain and Schwartz 1995). The foraging strategies used by the animal determine the intensity, timing and spatial location of plant defoliation and, consequently, the impact of patch grazing at the paddock scale.

Association with a specific land-type by free-ranging cattle can result in over-grazing, localised land degradation, increased soil erosion and loss of biodiversity in such areas. The relatively small size (92-115 ha) of the experimental paddocks at Wambiana has been identified as a factor affecting spatial grazing patterns. Spatial analysis of the GPS data, determined by the percentage of the paddock where the animal spent 95 % of its time (95% MCP), indicated that animals ranged over 85% of the paddocks on the Wambiana study site (Table 4.3). In some cases, it was calculated that individual animals accessed up to 98 % of their paddock (Table A9.1.3).

Cattle at Wambiana were not evenly distributed across the landscape (Figure 4.2). The GPS counts for animal occupancy in 25 x 25 m cells revealed definite areas of preference. However, it was not feasible to relate presence of an animal in a particular cell to grazing behaviour as the data would have been influenced by capturing "camp sites" associated with resting and rumination. A measure of animal activity, based on hourly distances travelled was therefore sued to indicate grazing/walking and resting/ruminating activity. While direct observations of grazing behaviour are tedious and time consuming they are possibly biased by the effects of human observers. Based on animal point density data (total count of GPS positions in each 25x25 m cell) the location of water appeared to influence cattle distribution (Figure 4.2). At Wambiana there was a significant (P<0.001) probability (0.98) that an animal would be adjacent to a water point (Tables 4.4, 4.5). Other sites that can be identified in Figure 4.2 which were not immediately associated with a water point could be interpreted as "camp sites" used for resting and rumination. Nevertheless, there was a greater probability of animals being associated with a water point compared with any other feature identified in the landscape.

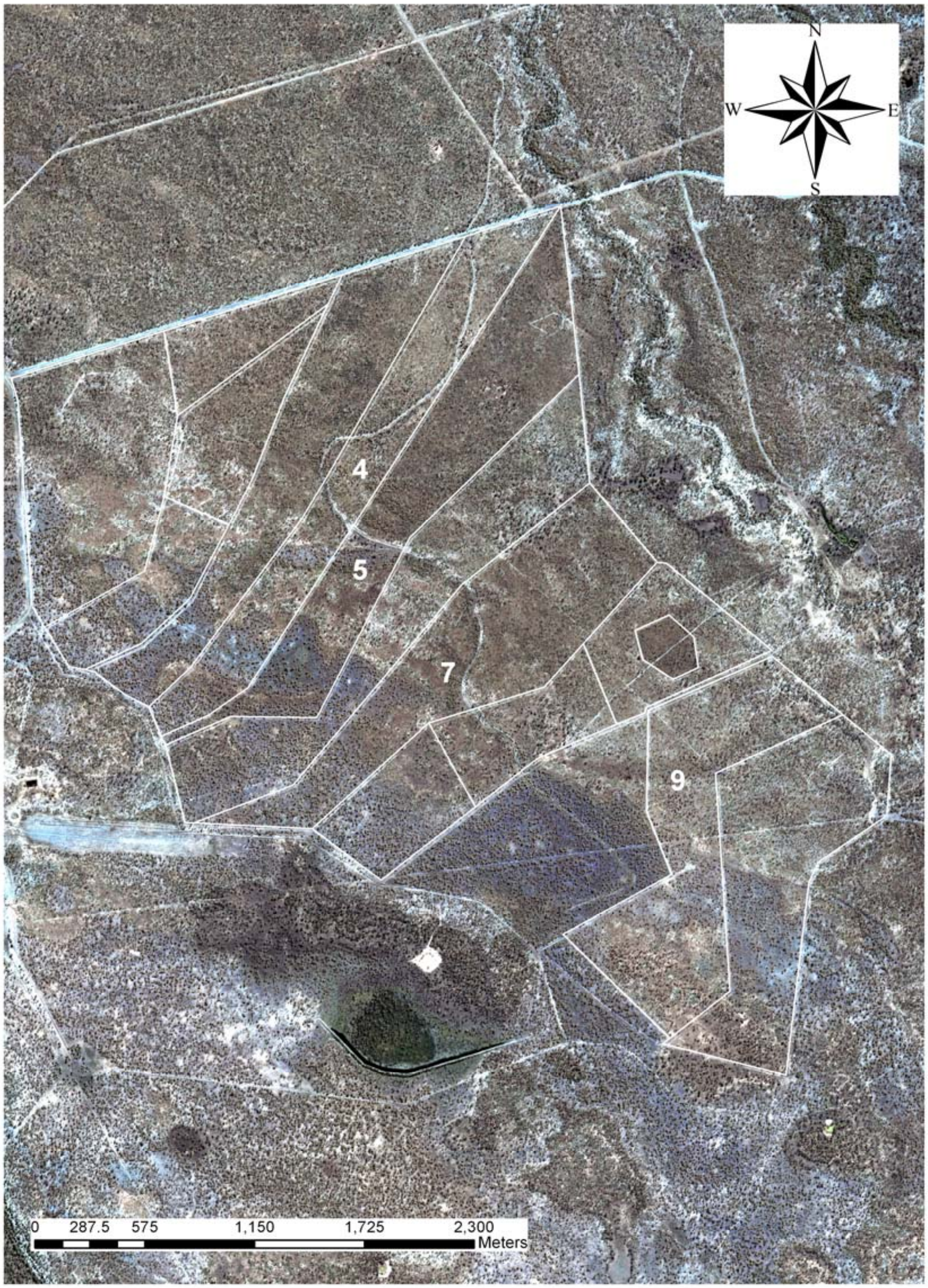

Figure 4.1 IKONOS image of the Wambiana study site. Experimental paddocks are identified; paddocks 4 and 9 were heavy stocked (4 ha / beast), paddocks 5 and 7 were light stocked (8 ha / beast) throughout the project.

Table 4.1 Mean* (±sem) total standing dry matter (TSDM, kg/ha) and projected ground cover (%) for light and heavy stocked paddocks based on land-type for the Wambiana study site

	Stocking rate			
Land-type	Light (8 ha / beast)		Heavy (4 ha / beast)	
	TSDM (kg/ha)	Projected ground cover (%)	TSDM (kg/ha)	Projected ground cover (%)
Coolibah	_	_	677 ± 177.8	29 ± 11.6
Black clay	920 ± 156.1	39 ± 2.5	140 ± 50.0	27 ± 4.3
Ironbark	686 ± 150.4	37 ± 4.4	172 ± 64.0	27 ± 4.1
Box annuals	_	_	120 ± 52.0	26 ± 4.4
Box Brigalow	571 ± 130.3	35 ± 7.1	180 ± 68.8	38 ± 11.1
Box Eremophila	995 ± 132.8	41 ± 7.6	140 ± 48.7	31 ± 7.8
Wet box	765 ± 232.1	36 ± 5.8	89 ± 76.2	28 ± 4.3
Box	1010 ± 156.1	29 ± 7.0	158 ± 44.5	29 ±2.2
Ironbark Ridge	_	_	178 ± 97.2	22 ± 5.1
Box Blackbutt	437 ± 216.7	17 ± 3.4	99 ± 34.8	25 ± 5.0

*values calculated from pasture surveys conducted in October 2004, April 2005 and October 2005 during the project.

The mean distance between individual collared animals and a water source was 1133 m for all deployments. However, cattle have been reported to travel between 2000 to 10000 m per day from water (Hodder and Low 1978; Ganskopp 2001). At Wambiana when animals moved away from one water point they were often moving towards a second water point. In addition the shape of the paddocks would have physically limited the range of individual animals. Consequently it was not possible to distinguish graduations in animal distribution, and therefore quantify the influence, between water points for each of the experimental paddocks at the Wambiana study site. Nevertheless, for extensive grazing situations there is sufficient evidence to indicate that cattle preferentially graze areas close to water (Lange 1969; Graetz and Ludwig 1978; Biograze 2000).

4.2.1 Modelling the biophysical determinants influencing grazing

Water points and fence lines consistently contributed to both the binary and Poisson models.

When the presence or absence of an animal, in relation to the unique characteristics of each cell, was described using the binary model, 5 of the 11 biophysical determinants (soil vegetation land-type association, tree cover, NDVI, pasture yield, broad soil group), made a significant contribution (Table 4.4). Of these, soil vegetation land-type association, tree cover and NDVI significantly contributed to the Poisson distribution model when the relationship of frequency of animal locations to characteristics of any particular cell was investigated (Table 4.4). However, neither tree cover nor NDVI data had a wide enough range to enable these variables to be used as predictors of animal location.

Land-type, based on soil and dominant vegetation, was identified as being the most likely to contribute to the presence or absence of an animal and the frequency of return visits in any one of the 25 x 25 m cells defined for the Wambiana study site.

Preference indices were calculated for; i) a spatial component based on 10 distinct land-types associated with the Wambiana study site (Table 4.5) and ii) a temporal element based on three broad soil groups and animal movement over 24 h periods. In general, the preference or use of land-types at Wambiana was related to their available proportion in the landscape. Preference ratio is simply the proportion of counts for animals in a land-type divided by the proportional area of that available land-type. Preferential selection for an area is indicated by values greater than one, whereas values less than one indicate avoidance. A value of one indicates that the animal neither favours nor avoids that area (Bowyer and Bleich 1984). For Box and Ironbark land-types, which comprised 68% of the grazing area, values were just less than one. Most water points, however, were in the Box and Iron bark land-types. It is probable that if water points had not been present, a more marked absence of animals in these land-types would have been apparent. For Box annual, Wet box and Coolibah land-types, which comprised <10 % of the grazing area, preference indices were 3.0, 3.24 and 5.79, respectively. The Box annual land-type was associated with duplex soils, *Chloris spp*. and *Chryspogon fallax* (an increaser species). The Wet box and Coolibah land-types were associated with heavy clay soils, 3P grasses (*B. ewartiana, D. sericeum),* sedges and in one paddock a water point. The preference indices for Wambiana indicated selection for land-types associated with heavy clay soils. However, in general these land-types were also associated with variable pasture production and anecdotal grazing preferences ranging from low to moderate. Only the Coolibah land-type was associated with high (>2000 kg / ha) pasture productivity and a moderate grazing preference.

Preference indices identified the least preferred land-types; Ironbark ridge and Box blackbutt which were associated with low to medium pasture production.

Based on the relationship between distances travelled per hour for individual animals and time of day (Figure 4.7) it was possible to identify daily activity patterns of collared cattle at the Wambiana study site. Apparent high activity or assumed grazing times were identified; namely 05:00 to 10:00h and 14:00 to 22:00h, were associated with animals travelling up to 500m in an hour and coincided with sunrise and sunset. Periods of low activity, or assumed resting/ruminating times, were associated with animals travelling a maximum of 250m in an hour and coincided with midday and midnight. When positional data was separated on the basis of high or low activity, it was apparent that cattle had a temporal association for certain land-types (Figure A9.3.1). However, this association was best described when land-types were aggregated into their respective broad soil group (Table 3.1). Preference indices were calculated for the three broad soil types at the Wambiana study site. Collared cattle grazed most intently at dawn (Figure 4.3b) and generally rested through the heat of the day (Figure 4.3c) in areas on clay soils. The mid day period was characterised by minimal activity and would equate to resting and ruminating. Around mid afternoon, sunset and through the evening cattle became active again and demonstrated a preference (values >1) for both clay and duplex soils (Figure 4.3d). Through the night and up to sunrise cattle then migrated to areas dominated by duplex soils (Figure 4.3a). At all times cattle appeared to have a lesser preference for land-types characterised by red/yellow earths compared with other areas.

The interpretation of the data to identify biophysical determinants driving patch and land-type selection based on preference indices must be treated with caution. When areas are over-grazed in larger paddocks (>1000 ha) they may become less attractive to livestock and a cycle of over-grazing is repeated elsewhere. This pattern was not apparent in the Wambiana study due to the small size of experimental units and low biomass availability across the paddocks for the majority of the project.

A more detailed description of the animal land-type associations are shown in Table A9.3.1

Table 4.2 Mean (±sem) total standing dry matter (TSDM, kg/ha) for heavy and light stocked paddocks at Wambiana for 2004-05 seasons

	Stocking rate			
	Heavy (4 ha / beast)		Light (8 ha / beast)	
	Paddock 4	Paddock 9	Paddock 5	Paddock 7
April 2004	488 ± 48.5	537 ± 161.9	1942 ± 211.6	1317 ± 148.6
October 2004	59 ± 9.7	140 ± 69.6	880 ± 145.9	533 ± 131.6
April 2005	234 ± 31.3	411 ± 79.7	986 ± 81.8	1167 ± 123.6
October 2005	60 ± 9.6	195 ± 71.2	715 ± 160.6	501 ± 70.5

Table 4.3 Mean (±sem) 95% minimum convex polygons (MCP) for cattle fitted with GPS units, Wambiana

	Stocking rate		
	Heavy (4 ha / beast)	Light (8 ha / beast)	sem
MCP (ha)	83.2^{a}	97.8^{b}	5.26
(% available)	84.6	84.9	4.66

Means with different superscripts are significantly different (*P*<0.05)

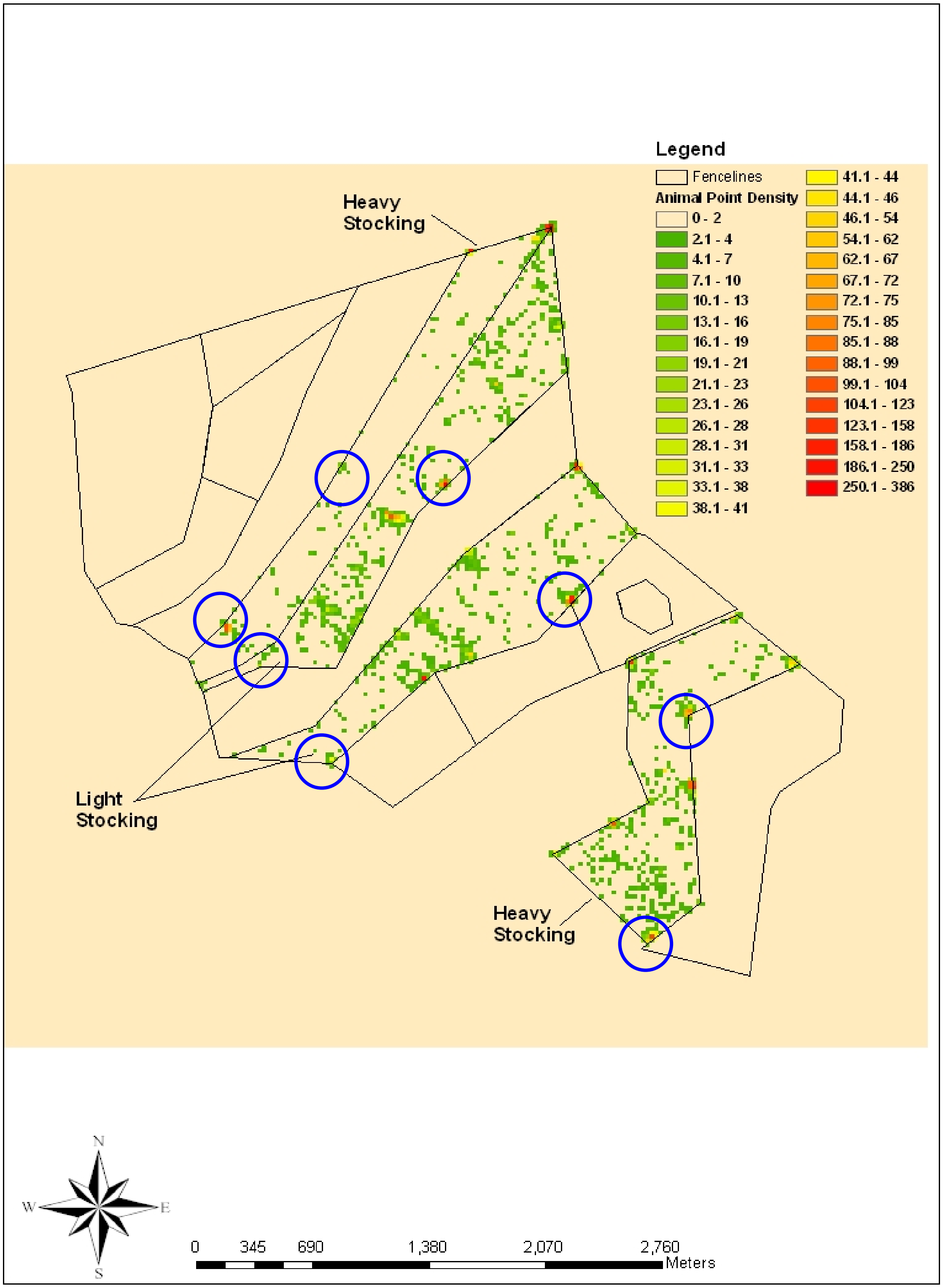

Figure 4.2 Animal point density (total count of GPS positions in each 25x25 m cell) for the Wambiana study site. Approximate location of water points in each paddock is circled

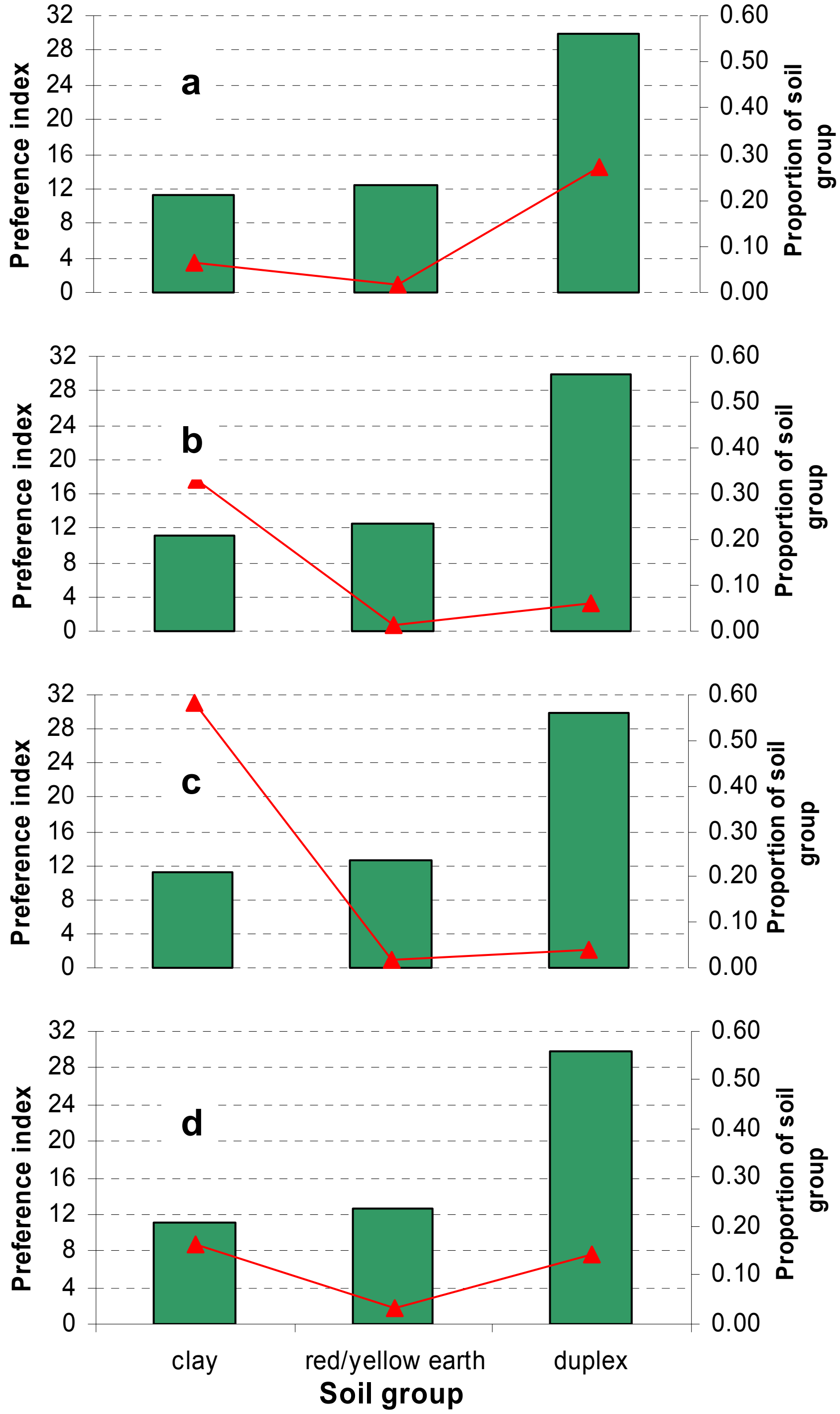

Figure 4.3 Preference indices (▲ ;< 1 aversion, 0 no preference, >1 preference) in relation to the proportion of broad soil group available (■) at the Wambiana study site based on daily activity patterns. **a)** resting/ruminating 22:00-05:00 h, **b)** grazing/walking 05:00-10:00 h, **c)** resting/ruminating 10:00-14:00 h, and **d)** grazing/walking 14:00-22:00 h

Table 4.4 The significance of biophysical determinants to the Binary and Poisson models used to describe animal distribution in experimental paddocks, Wambiana study site

Biophysical determinant	Significance for binary model	Significance for Poisson model
Soil vegetation - land-type association [D]	$P<0.001$	$P<0.001$
Statewide Landcover and trees study (tree cover) [C]	$P<0.001$	Significant, but range too narrow for analysis
Normalized differential vegetation index (NDVI) [C]	$P<0.001$	Significant, but range too narrow for analysis
Soil type [D]	$P<0.001$	$P>0.05$
Pasture yield [C]	$P<0.001$	$P>0.05$
Ground cover [C]	*0.523*	$P>0.05$
Soil N [C]	$P>0.05$	$P>0.05$
Soil P [C]	$P>0.05$	$P>0.05$
Soil K [C]	$P>0.05$	$P>0.05$
Water [D]	$P<0.001$	$P<0.001$
Fence line [D]	$P<0.001$	$P<0.001$

[C]continuous, [D]discrete variables

4.3 Assessing the relationships between land-type selection and soil/vegetation types for large commercial properties

It is recognized that the Wambiana study site was atypical of most northern Australian grazing situations in terms of size and shape of paddocks. However, the project has allowed for intensive measurement of landscape attributes in a replicated design. The Trafalgar study site was chosen to be representative of commercial properties, but lacked the richness of data and replication. There were also important differences in land-type between the study sites. This section assesses the predictive applicability of the Wambiana data to a large commercial sized paddock.

The commercial paddock was characterized by a relatively flat area of improved pasture and areas of steep, stony slopes. The former area was highly attractive to cattle whilst the latter was avoided. The study used mature cows, with calves, which have been shown to generally travel less than yearling cattle (Arnold and Dudzinski 1978). In addition, the commercial paddock had been previously spelled, and this may have contributed to the observed change in livestock behaviour over time. At Wambiana, steady state grazing behaviour was expected. Nevertheless, some important conclusions can be drawn from the commercial paddock and Wambiana data sets.

Minimum convex polygon analysis for the Wambiana data revealed that practically the entire paddock, regardless of stocking rate, were frequented by livestock (Table A9.1.3). In contrast, initial grazing preference in the commercial paddock was centred on a relatively flat, cleared 250 ha of improved pasture (Buffel grass). With time, mean MCP increased as cattle grazed out this area and moved onto other less palatable species associated with adjoining uncleared *A. agyrodendron* native pasture woodland. Figure 4.4 indicates the occupied proportion of land area in the commercial paddock. Continuous 24 h GPS data from three collared animals indicated that after three weeks, only 29% of the study area had been utilized. Figure 4.5 indicates that MCP was time dependent. This is consistent in situations where animals have no pre-harvest information, but acquire knowledge of the distribution of patches in their environment (Valone 1991, Klaassen *et al*. 2007) and in the commercial paddock animals moved onto patches associated with uncleared *A. agyrodendron* native pasture woodland.

Table 4.5 Available proportions, used proportions, preference and standardised indices and the probability of selection for water points, fence lines and different land-types based on soil /vegetation classes for Brahman cross steers, Wambiana study site

	Available proportion[1]	Used proportion[2]	Preference index[3] (w_i)	Standardised index[4] (B_i)	Probability of selection[5]
Water point/s					0.98
Fence line					0.55
Land-type					
1. Coolibah[6,7]	0.006	0.032	5.79	0.34	1
2. Black clay	0.168	0.179	1.07	0.06	0.41
3. Ironbark	0.216	0.200	0.92	0.05	0.36
4. Box annuals[8]	0.010	0.029	3.01	0.18	0.61
5. Box Brigalow	0.027	0.019	0.72	0.04	0.47
6. Box Eremophila	0.083	0.077	0.93	0.05	0.40
7. Wet box	0.011	0.036	3.24	0.19	0.54
8. Box	0.468	0.420	0.89	0.05	0.44
9. Ironbark Ridge[7]	0.019	0.005	0.28	0.02	0.30
10. Box Blackbutt	0.026	0.003	0.12	0.01	0.27

[1]size of land-type / total size of study area, [2]count of animal locations per land-type / total count, [3]proportion of used / proportion available land-type (Hobbs and Bowden 1982), [4]$B_i = \hat{w_i} / (\sum_{i=1}^{I} \hat{w_j})$ (Manly *et al*. 1972) [5]Log linear regression model estimate. [6]Reference land-type. [7]Indicates selection for heavy stocked animals only, [8]indicates selection for light stocked animals only.

When allometric rescaling, based on spatial relationships using mean values from three animals for continuous 24 h GPS data at the Wambiana site, was used to estimate the MCP (ha) and distances travelled (m/d) by animals in the commercial sized paddock, MCP was under-estimated by 52% (observed 191.6 ha *vs*. expected 91.7 ha) and distances travelled were over-estimated by 31% (observed 7739 m vs. expected 11188 m). The size and shape of paddocks have been recognised as influencing grazing behaviour, and consequently distances travelled by stock (Pringle and Landsberg 2004). The marked differences in land-type between the Wambiana study site and the commercial paddock would have also influenced animal distribution. Nevertheless, it is apparent that the MCP and distances travelled by cattle in the experimental paddocks at the Wambiana study site were unsuitable proxies, based on allometric rescaling, for predicting MCP or distances travelled by cattle in a commercial (~1500 ha) paddock.

Land-type, based on soil and dominant vegetation, was used as a biophysical determinant for the study in the commercial paddock. Spatial analysis of the data over time indicated that initial grazing preference and home range were initially centred on the water point and an area of improved pasture (Buffel grass) on texture contrast and clay soils which was also relatively close (within 4.1 km) to water (Figure 4.4). Consequently, grazing pressure was concentrated on areas close to water which presumably offered the greatest intake rate of digestible energy. Thereafter, animals moved on to adjoining, uncleared *A. agyrodendron* native pasture woodland and less fertile, outlying areas of *Eucalyptus* woodland.

Selection indices based on all data collected over the eight week deployment of GPS collars clearly confirmed the grazing preference for Buffel grass (Table 4.6 & Figure 4.6). This was expected, particularly in light of rainfall which fell during the study period. Buffel grass responded quickly to rainfall with new growth of high quality forage. Cattle almost completely avoided open *E. melanophloia* (Silver- leaved Ironbark) woodland on stony open hill slopes immediately east of the cleared area, presumably because of its very low cover and relatively infertile soils. The steep stony terrain may have also acted as a physical barrier to grazing. Selection indices indicated that almost 0.48 of the paddock had a forage or preference index <0.25. This included areas which were also associated with coarse unpalatable grasses namely *Eriachne ssp*, (an increaser species), and Spinifex.

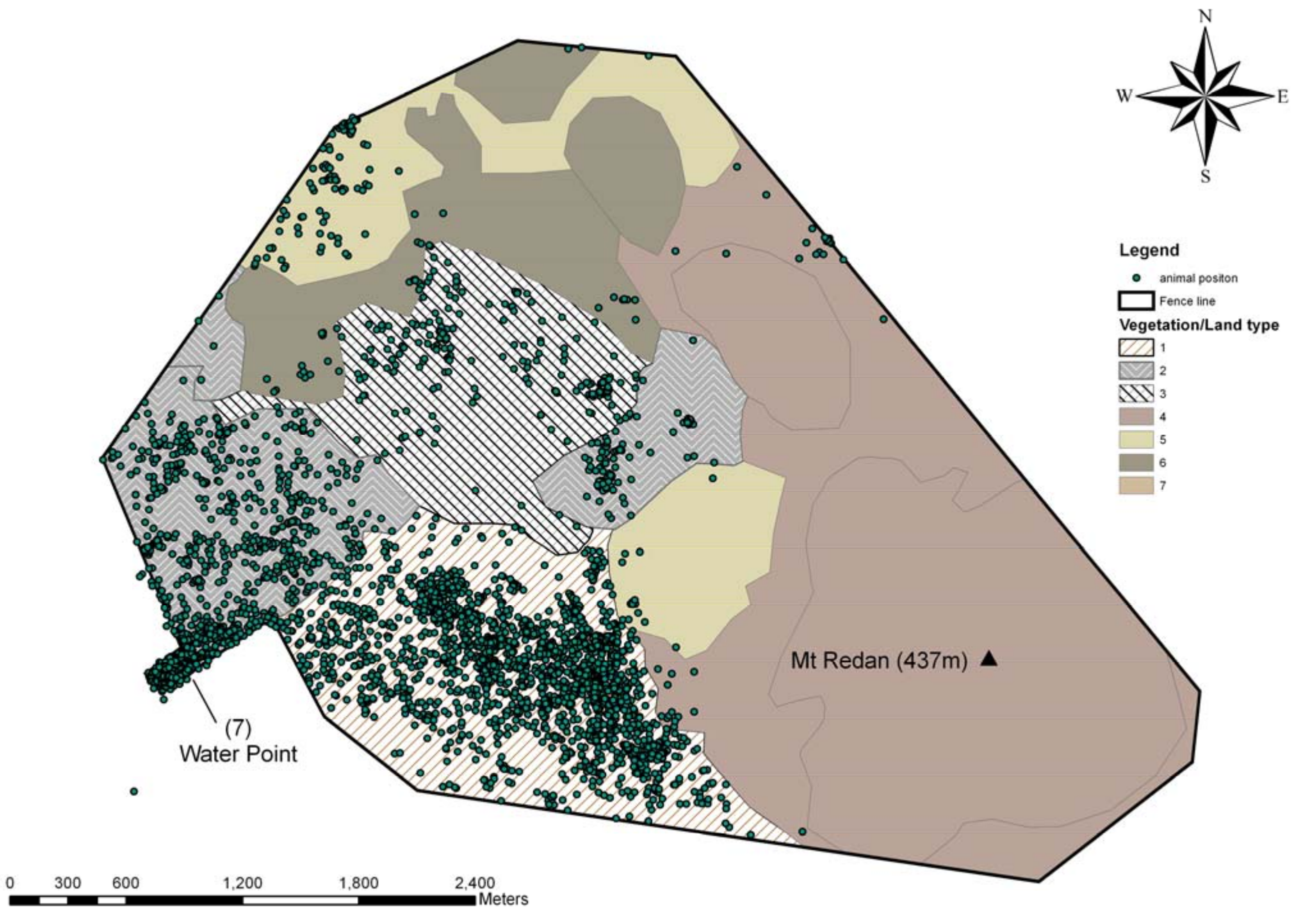

Figure 4.4 The grazing distribution of Brahman cows (*n*=7), each fitted with a GPS collar for eight weeks in a commercial paddock, Trafalgar Station. Numbers in legend indicate different land-types based on soil and dominant vegetation; *1*) Cleared Blackwood (*A. argyrodendron)* woodland on heavy clay and duplex soils, *2*) Intact Blackwood woodland on heavy clays and duplex soils, *3*) Open Box (*E. brownie*) woodland on texture contrast soils with Narrow-leaved red ironbark (*E. crebra)* in places, *4*) Silver-leaved ironbark (*E. melanophloia*) with *Acacia spp*. and some Narrow-leaved red ironbark on shallow texture contrast soils, *5*) Narrow-leaved red ironbark on red soil, *6*) Silver-leaved ironbark with some Lancewood (*E. shirleyi*) and wattle thickets on stony shallow soils, *7*) Fenced area < 1ha, subset of (*1*).

Table 4.6 Available proportions, used proportions, forage ratios and the probability of selection for different land-types based on soil /vegetation classes for Brahman cows, Trafalgar Station

	Available proportion[1]	Used proportion[2]	Preference index[3] (w_i)	Standardised index[4] (B_i)
Water point	0.002	0.17	85.0	0.94
Land-type				
1. Buffel	0.16	0.55	3.4	0.04
2. Blackwood	0.13	0.18	1.4	0.02
3. Box	0.11	0.05	0.45	<0.01
4. Ironbark[5]/yellow earth	0.38	0.01	0.03	<0.01
5. Ironbark[6]/red earth	0.11	0.03	0.27	<0.01
6. Ironbark[5]/shallow soils	0.11	0.01	0.09	<0.01

[1]size of land-type / total size of study area, [2]count of animal locations per land-type / total count, [3]proportion used / proportion available land-types (Hobbs and Bowden 1982), [4]$B_i = \hat{w}_i / (\sum_{i=1}^{I} \hat{w}_j)$ (Manly *et al*. 1972), [5]*Eucalyptus melanophloia*, [6]*E. creba.*

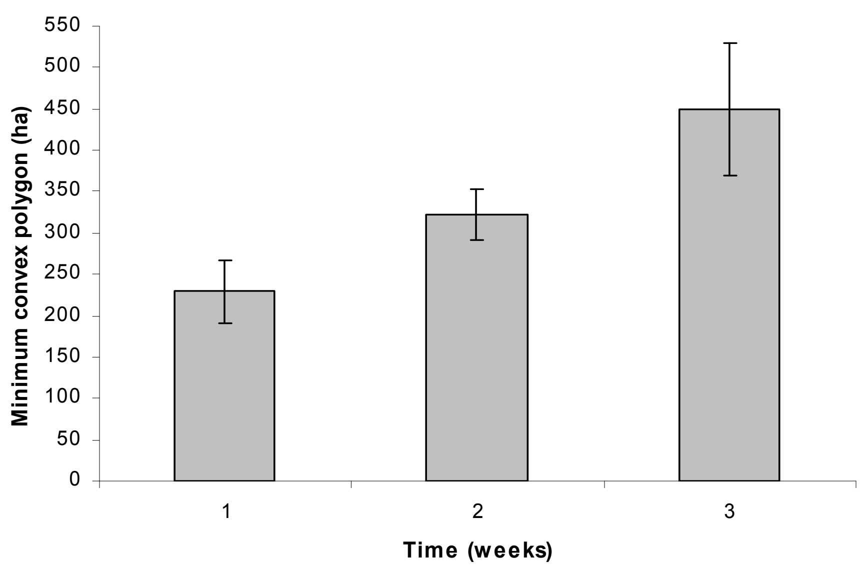

Figure 4.5 Mean (±sem) minimum convex polygon values, determined from continuous 24 h positional data for the first three weeks of the study period in a commercial paddock, Trafalgar Station, for Brahman cows (n=3) fitted with GPS collars.

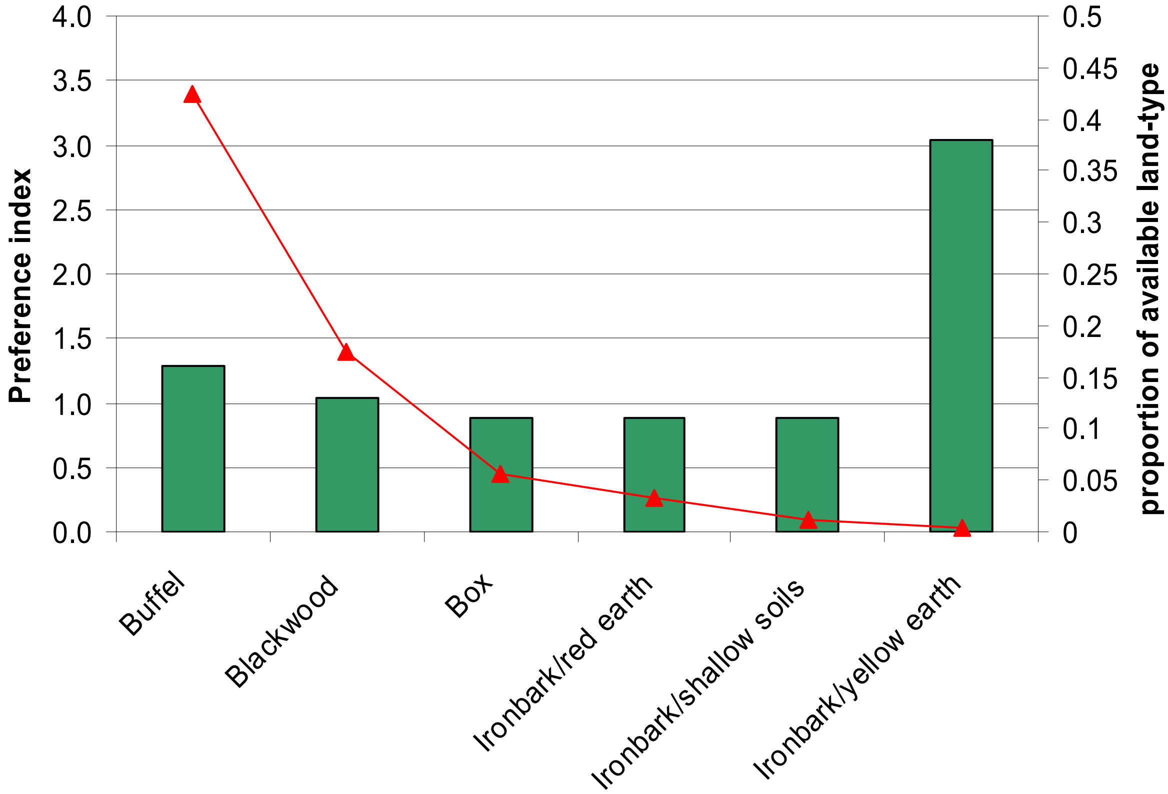

Figure 4.6 Preference indices (▲) in relation to the proportion of land-type available (■) in a commercial paddock, Trafalgar Station (<1 aversion, 0 no preference, >1 preference)

4.4 Additional findings relevant to the project

4.4.1. Temporal effects on activity.

Frequent GPS locational data allows a temporal pattern of livestock movement to be generated. Calorimetric studies have indicated that the energetic cost of walking for ruminant animals ranges from 2.0 kJ / km, for a horizontal component, to 28.0 kJ / km, for a vertical component (SCA 1994). Consequently, in large paddocks animals may expend a considerable portion of their daily metabolisable energy intake on movement while grazing heterogeneous pastures. In calculating distances travelled, it is assumed that cattle travel in a straight line between consecutive GPS points. However, this is an idealised assumption and not necessarily correct when animals move between and within patches. The relationship between GPS fix rate (number of GPS locations which are required per h) and the calculated distance travelled per day for grazing cattle has been investigated. Increasing the frequency of GPS fixes per hour results in an increase in the calculated distance travelled in an exponential manner (R^2=0.93; Figure A9.2.1). As expected, an increase in fix rate would capture more discrete straight-line paths during a specified time and result in a better estimate of actual distances travelled by the animal. It is not known at this stage if an increase from two to three fixes per hour would significantly improve the estimate of distances travelled. The consequences of an increase fix rate on power management are discussed in section A9.2.

At Wambiana, there was no significant difference (P>0.05) in mean distance travelled, per hour or per day, for heavy compared with light stocked animals (Table 4.7). Although there was considerable variability between individuals, mean distances travelled by cattle, calculated on an hourly basis for 24 h in the light and heavy stocking groups, continued to indicate clear patterns of activity (Figure 4.7). Regardless of stocking rate, peak periods of travel were confined to dawn and dusk, which were probably the main grazing times. Cattle converged on water points late in the morning and returned to grazing during the afternoon. During these times animals travelled up to 1500 m over a two hour period.

In the commercial paddock, peak periods of travel were the same as those observed at Wambiana. Perhaps, surprisingly, given the 15-fold difference in paddock size, cows in the commercial paddock did not necessarily travel proportionally further compared with steers at Wambiana. Allometric rescaling of the Wambiana data to the commercial paddock demonstrated that the predicted distances travelled in a commercial paddock would be over-estimated. It was concluded that the proximity of good grazing to the water point contributed to distances being less than expected. It is also recognised that cows with calves at foot are less likely to travel as far as steers (Arnold and Dudzinski 1978). The size and shape of paddocks has also been recognised as influencing grazing behaviour, and consequently, the distances travelled by stock (Pringle and Landsberg 2004).

Table 4.7 Mean (± sem) distances travelled per hour and per day for cattle fitted with GPS units, Wambiana study site.

	Stocking rate		
	Heavy (4 ha/beast)	Light (8 ha/beast)	sem
Distance travelled			
m / h	254.0	229.2	29.38
m / 24 h	6967.0	6262.0	681.8
Distance from water			
Northern trough, m	1007.8^{a}	722.4^{b}	207.3
Southern trough, m	1423.0^{a}	1708.0^{b}	143.0

Means with different superscripts are significantly different (P<0.05)

In the commercial paddock, drinking events, determined by proximity to water, were also evident during dawn and dusk. On occasions, some animals did not return to the water point for up to three days. It is possible that these individuals were utilising small ephemeral waterholes during this time. There was considerable variation between cows in distances travelled over 24 h and between assumed drinking events (Table 4.8).

Table 4.8 Mean (± sem), minimum and maximum distances travelled per day, range* and return distance from a single water point for Brahman cows fitted with GPS collars in a commercial paddock, Trafalgar Station

	Mean ± sem	minimum	maximum
Distance travelled per day, m/24 h	8127 ± 267	3648	14698
Range* from water, m	1464 ± 13.7	_	4125
Distance travelled between visits to water (m)	13811 ± 4770	5186	26670

*maximum calculated distance from water

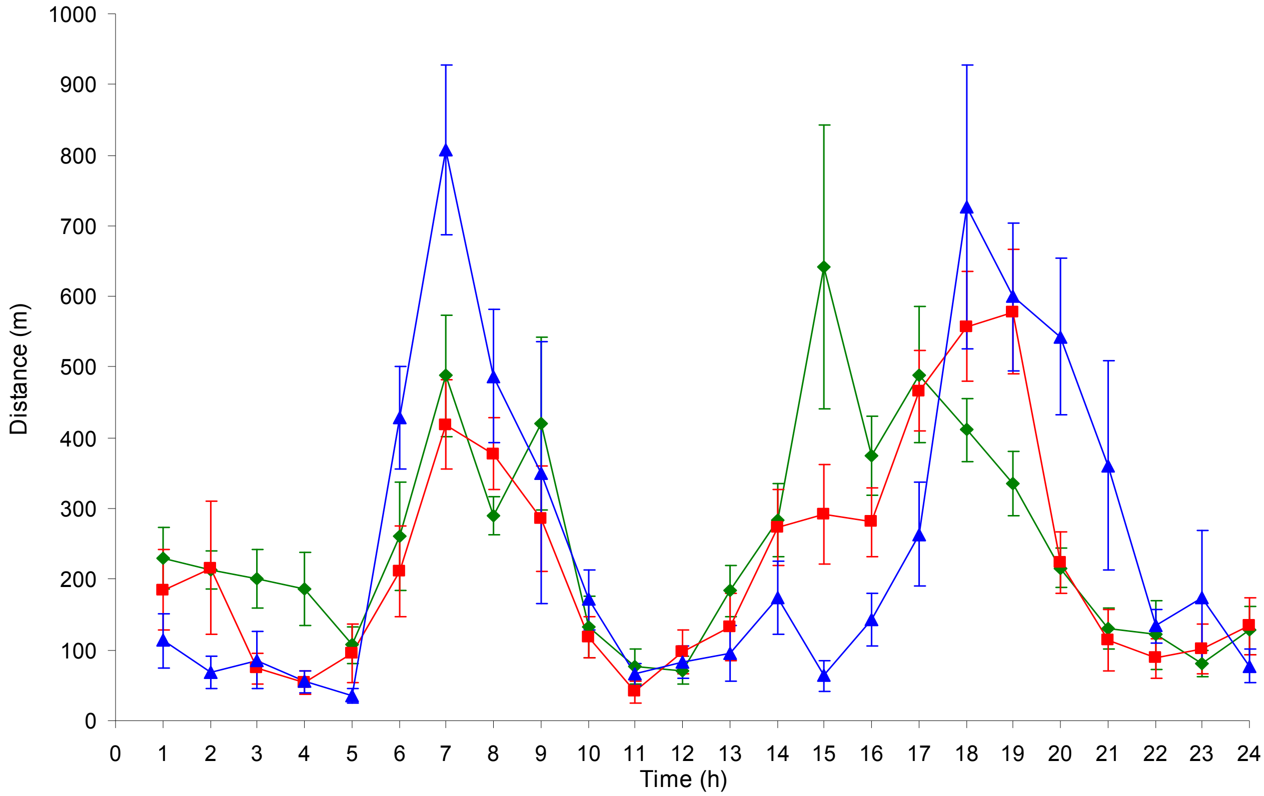

Figure 4.7. Mean (± sem) distance travelled, per hour over 24 h, by animals fitted with GPS units. Brahman cross steers in experimental paddocks, Wambiana (■ light stocking; 8 ha/beast, ♦ heavy stocking; 4 ha/beast). Brahman cows in a commercial sized paddock, Trafalgar (▲)

4.5 Technical difficulties and lessons learned

Details of the technical challenges encountered during these studies are given in Appendix 9.2. In this section, these challenges are discussed in the context of how this technology can be used in northern Australia.

4.5.1. Success of data collection

There were two components to GPS collar functionality; the proportion of the deployment period when the collars were functioning and the rate of obtaining a GPS position from a minimum of four satellites during this time (Figure 4.8). When GPS collars were first deployed the duration of functionality was greater than 80% of the deployment period and considered satisfactory. However, in each successive deployment the mean period of functionality declined. By the time of the commercial deployment, GPS collars only functioned for 15% of the deployment period. This was determined on data retrieved from seven of the 12 collars. All collars were working when deployed. Data from five of the collars could not be retrieved. GPS positions may have been collected, but could not be downloaded due to inherent corrosion in the GPS circuit boards affecting data transfer. Following the Trafalgar deployment all collars were extensively repaired and functionality was improved by 14.5 percentage units.

Field conditions during the third deployment at Wambiana contributed to serious degradation of the GPS units. Humidity, high temperatures and physical impact would have been factors leading to diminished functionality of the units. However, the structural integrity of collars was considered reasonable even after five deployments. The major cause of eventual failure was attributed to battery related problems and is discussed in Section 4.3.3.

4.5.2. Securing a GPS fix

The second aspect of GPS collar functionality relates to obtaining a GPS position.

Obtaining a GPS position is dependent on configuration of available satellites and their visibility to the antennae, both of which can vary considerably over a 24 h period.

For a GPS position to be logged by the unit, a minimum of four satellites was required throughout the project. The positional data was, in general, obtained from an average of five satellites during the deployments at the Wambiana study site. Programming the GPS units to "search" for more satellites over a period greater than 300 s to determine a position is possible. However, this creates two new problems; firstly the time taken to acquire a GPS position can deviate significantly within the programmed period (up to 300 s). This introduces an additional variable when temporal relationships are being investigated and short "fix windows" are preferred to avoid temporal drift of data sets. Secondly battery life can be considerably shortened if units continue to search for more satellites to determine a position. The "fix window" chosen for this project was determined as satisfactory during tests at Rockhampton. However, during the five deployments, field conditions in northern Queensland would have been variable, and at times, less than optimum.

The preferred location for the GPS antenna on the animal is on the dorsal surface (top of the neck, in the case of a collar mounting). The pronounced elliptical neck on Brahman and Brahman cross cattle resulted in the antennae slipping to the left or right of the dorsal surface of the neck. Orientation of GPS antennae may affect the determination of a position if the required minimum numbers of satellites are not visible. It has been demonstrated that both collar position and individual animal activity during different times of the day are a large potential source of error and bias for obtaining GPS locations (D'Eon and Delparte 2005). It is not unreasonable to conclude that these factors were influencing the fix rates obtained at both study sites during this project.

The GPS collars have since been completely redesigned (Figure 4.10) and the new version now appears to have resolved the problem associated with collar orientation.

Tree and cloud cover also potentially interfere with obtaining a GPS position. At the two study sites, tree cover, based on crown types (McDonald *et al.* 1998), was considered sparse to moderate and determined not to have had a substantial affect on acquisition of GPS positional data.

Cloud cover was an unaccountable variable in the wet season deployments. Scattered falls through December and January during the commercial deployment indicated adequate cloud cover for rain, about 121 mm in total, and this may have been sufficient to affect acquisition of GPS positional data because the satellite criterion (≥ 4 satellites) was not satisfied. Regardless of site, cloud cover cannot be predicted or eliminated.

Figure 4.8 shows that success rate (a percentage of total possible GPS positions when collars were functional) was high (>70%) in deployments 1 and 3. These occurred in the dry season, when cloud cover would have been minimal. During the wet season, deployment success rates were lower (~55 %). The 11.5 y average number of cloudy days for October was 10.2 compared with 20.3 for February. For the commercial deployment, success rate was approximately 55%.

For the first three deployments at Wambiana and for the commercial deployment, a no positional data fault, indicating that at least four satellites could not be found within 300 s, accounted for up to 24% of potential fixes. However, in the last deployment at Wambiana, approximately one third of faults were attributed to GPS unit failure (Figure 4.9).

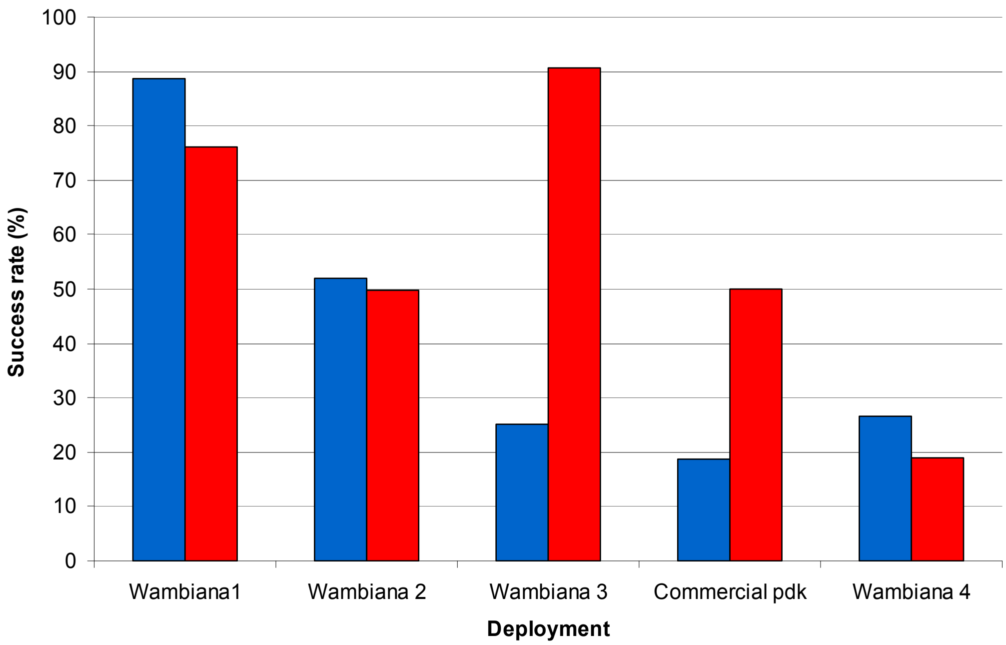

Figure 4.8 The effective operation of GPS units during Wambiana and commercial deployments. Proportion of deployment period when units functioned (■). Proportion of successful GPS fixes, collected from a minimum of four satellites, during each deployment (■)

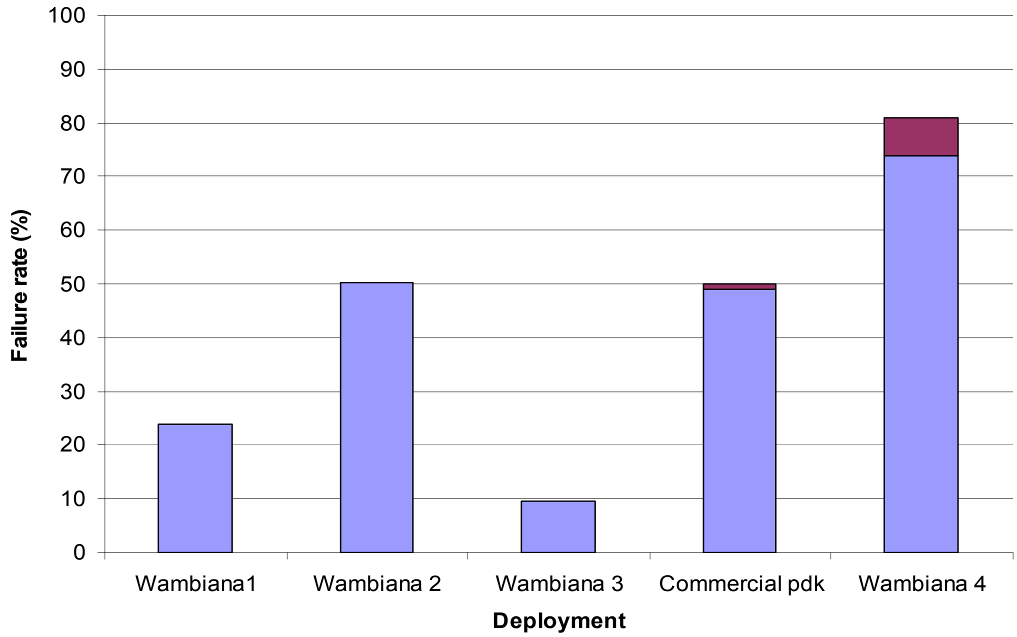

Figure 4.9 Status of GPS faults during Wambiana and commercial deployments. No positional data (■), where < 4 satellites were found and GPS receiver fault (■) where unit failed to operate.

Figure 4.10 GPS collars have been re-designed to facilitate better placement of the GPS antennae and easier fitting to animals

4.5.3. Battery life and failure

The primary cause of GPS unit faults was related to battery failure.

Initially AA and C cell batteries were used to power the GPS units, but in some cases batteries discharged during a deployment. For the third deployment, the AA batteries were upgraded to high drain, high capacity units. However, this inadvertently resulted in an uneven discharge of the batteries, the C cells leaked and consequently corrosion affected the components on the circuit board.

Continuous exposure to high temperatures also caused premature failure of the batteries. Sensors in the GPS units recorded temperatures of up to 50 °C, for which the batteries were not rated, and recommended maximum operating temperature for the units themselves was 54 °C. It is likely that "thermal runaway" also compounded the problems and affected the functionality of the GPS units.

For subsequent deployments, all batteries were changed to AA E2 Energizer® lithium batteries. These batteries were "long life" and rated to temperatures of up to 60°C. Although these functioned satisfactorily, inherent corrosion in the circuit boards resulted in a rapid decline in GPS functionality. Of the 12 original units, six have been discarded and six have been completely refurbished with new components.

5. Success in achieving objectives

This study was among the first of its kind in the sub tropical savannas of northern Queensland. Some of the objectives outlined in the proposal proved to be poorly aligned with the nature of the work, capabilities of the equipment and were not met. However, the study has provided a wealth of information regarding the practical aspects of conducting this type of work, as well as useful data and information that was not aligned with the objectives.

The project has proved to be an important pilot trial. Lessons learned from the Wambiana and commercial deployments will be invaluable for conducting future work and building robust data sets for modelling purposes.

5.1 Quantify the impact of utilisation rate on patch and landscape selection by cattle at Wambiana

The study conducted at Wambiana was only able to quantify the impact of utilization (stocking) rate. The prevailing drought conditions, and failure of the wet season, during the study affected biomass availability and hence selection pressure. Actual calculated utilisation rates were very different, median utilisation was 35 % and 75 % for the light and heavy stocked treatment groups, respectively, during 2004/05 (O'Reagain *pers comm*. 2006). Molasses (M8U) supplementation was required to maintain animal condition and some live weight gain. In the light stocked paddocks animals were under less pressure to graze selectively, but were still forced to broaden their grazing preference compared to a "normal" season. All land-types were grazed in the heavy stocked paddocks because biomass availability was limiting. For both stocking rate treatment groups three of the identified land-types were "used" or occupied in proportion to their availability. Due to the reliance on occupancy data to determine land-type selection and the absence of well defined patches across the experimental paddocks there was insufficient data to measure specific patch selection. Nevertheless, three land-types could be

identified as having a high measure of preference; Coolibah, Wet box and Box annual. When related to the broad soil groups identified for Wambiana Coolibah and Wet box land-types were also indirectly associated with grazing activity.
This objective has been partially met.

5.2 Identify the major biophysical determinants driving patch and land-type selection at Wambiana

This project has demonstrated that GPS and satellite imagery can be used in the tropical savannas to determine preference indices and probabilities of selection for grazing cattle based on bio-physical determinants. Areas susceptible to over-grazing, based on land-type can be identified. Of the 11 determinants identified and applied to the conditional models in this study, only land-type was a significant driver for patch selection. Additional bio-physical determinants may be identified for different sites and are presented in Appendix 9.4.

The location of artificial water points influenced the distribution of grazing animals. However, the location of multiple water points confounds interpretation of data when the concept of a piosphere is applied to individual water points in small paddocks (~ 100 ha). The location of a water point was associated with a high probability of an animal location. However, at Wambiana it was not a major biophysical determinant driving patch and land-type selection because the size and shape of the paddocks were likely to have had a greater effect on grazing patterns (Pringle and Landsberg 2004).

The major biophysical determinants that appeared to influence land-type selection at Wambiana were the dominant vegetation and soil types. Pasture yield, NDVI and tree cover data were identified as contributing to the presence/absence model, but under the conditions experienced at Wambiana could not be divided into biologically meaningful classes to ascertain at what level these variables influenced patch and land-type selection.
This objective has been satisfied.

5.3 Construct robust empirical relationships that relate patch and land-type selection by grazing cattle to soil and vegetation characteristics for Wambiana

To develop a better understanding of the GPS data a non-linear spatially explicit model was initially proposed. In validating an existing grazing distribution model with paddock data from Wambiana it was found that a spatially predictive model, incorporating landscape variables, could not be developed from the data available. In February 2006, CSIRO Livestock Industries, QDPI&F and MLA redefined the modelling requirement of the project. It was agreed that a multiple variable analysis approach would be used to predict the probability of animal location based on biophysical (landscape) determinants. Subsequently, a conditional model, based on 11 biophysical determinants to describe animal-land-type associations was used to analyse the spatial data. The probability of animal location was based on the land-types identified at Wambiana according to soil and dominant vegetation type. Grazing animals clearly exhibited a preference for heavy clay and duplex soils that were associated with Coolibah, Wet box and Box annual vegetation types. Pasture yield contributed to the presence/absence component of the model only. The range of values for NDVI, tree cover and pasture yield were not sufficiently large to assign probabilities based on discrete classes.

Relationships between soil and vegetation characteristics for Wambiana and patch grazing have been identified. A robust, empirical model was not developed.

The original objective was not achieved.

A modified objective, defined in consultation, has been met.

Test empirical relationships that relate patch and land-type selection by grazing cattle to soil and vegetation characteristics for Wambiana, in a large commercial paddock

At Wambiana, land-type was found to be the dominant driver for landscape selection. Six different land-types, based on soil and dominant vegetation, were identified for the commercial paddock. However, these were quite different to those at Wambiana. Nevertheless, it was found that land-type continued to influence grazing patterns in a large (>1000 ha) commercial paddock.

This component of the project confirmed that grazing preferences can be interpreted through GPS and satellite imagery for commercial operations. Areas susceptible to over-grazing, based on pasture or land-type and proximity to water, can be identified.

This objective has been met.

5.4 Develop preliminary management guidelines to enable graziers to manage large, spatially heterogeneous paddocks in a sustainable and productive manner

The studies conducted at Wambiana and Trafalgar Stations have demonstrated that GPS and satellite imagery can be used to determine preference indices and probabilities of selection for grazing cattle based on defined bio-physical determinants. This research has been able to quantify and rank livestock preferences for particular land-types. It has shown that land-type is a strong driver influencing patch grazing. While this information is useful for research, currently it has limited applicability to graziers.

The results obtained from this project are based on a very limited dataset. A small number of animals have been used to represent a larger herd and studies have been conducted on two very different sites. Consequently, the development of any guidelines based on this dataset that would enable graziers to manage large, spatially heterogeneous paddocks in a sustainable and productive manner, in addition to current best practice for determining property infrastructure, should be treated with caution.

Based on selection indices for pasture or land-type, and proximity to water, particular areas can be identified as susceptible to over-grazing. This information may form the basis of management guidelines, but guidelines will only become more robust, and generally applicable, with the inclusion of additional data. Larger data sets will remove the biased generated by sampling only a small proportion of the population, or herd, and remove the idiosyncrasies associated with individual animal measurements.

Management guidelines will be determined by the extent of GIS or field data collected to identify relevant bio-physical determinants. Potentially relevant bio-physical determinants are listed in Appendix 9.4. These are expected to be property specific as land-types and regions must be considered independently.

Preliminary management guidelines may include fencing to land-type, positioning water points relative to land-type and paddock size/shape, and allocating seasonal yield values to patches with a history of preference. The latter may be determined by satellite imagery or a recognised pasture assessment technique and permit stocking rates to be managed by specific land and/or soil type.
This objective has not been met.

Further work will be required across a number of larger scale paddocks in the tropical savannas to clearly define a suite of bio-physical determinants that can be applied to individual properties and land-types relevant to the northern beef industry.

6. Impact on meat and livestock industry – now & in five years time

By its nature this project was not intended to have a direct impact on the meat and livestock industry. The project was exploratory in nature.

The use of GPS technology in association with GIS to better understand and eventually predict patch grazing in heterogeneous environments has been assessed under experimental and commercial conditions. The technology is still in the developmental phase and the extreme conditions encountered in this trial were a challenge for the hardware.

In five years time, it would be realistic to expect that the conduct of similar studies would be routine, conducted on a larger scale and at a reduced cost. Extensive data acquisition will be useful in developing predictive models of patch grazing in heterogeneous environments. The effects of adopting alternative grazing practices that may involve paddock subdivision, managed access to strategic water points or fencing of riparian areas on grazing animal distribution can now be quantified using GPS devices.

With the development of more sophisticated activity sensors that differentiate between biting, masticating and drinking and/or the incorporation of post processing algorithms that interpret higher positional fix rates in terms of velocity and changes in direction, a far more comprehensive understanding of grazing animal behaviour in variable landscapes can be acquired. This information would be of direct relevance to the grazier where GIS databases, at an appropriate scale for a property, may be freely available.

The use of models to predict grazing dynamics, and the likelihood of overgrazing particular land-types, will be a specific tool to assist to industry maintain and/or improve land condition while achieving economically sustainable stocking rates.

Given the size of the industry and the expected increase in the breeder herd on grazing lands, grazing pressure will increase. Increased concern for positive environmental outcomes and sustainability metrics becoming tied to land tenure will require graziers to modify existing best management practices for both production and sustainability outcomes.

7. Conclusions and recommendations

Quantifying patch and landscape selection

- The results obtained from this project are based on a very limited dataset and rely entirely on occupancy of animals in areas based on a 25 x 25 m grid.
- The use of GPS devices can result in defining grazing animal distribution patterns.
- Preference indices to detect patch selection were derived for individual land-types and the major soil groups.
- Collared animals clearly showed an overall preference for Coolibah, Wet box and Box annual land-types at the Wambiana study site.
- Collared animals clearly showed an overall preference for areas of improved pasture (Buffel) and Blackwood land-types on heavy clay and duplex soils at the commercial study site.
- Diurnal patterns of animal activity were consistent with other extensive grazing studies and indicated a grazing preference for land-types generally associated with clay soils.
- The use of distances travelled per hour to define animal activity was used as an indicative measure for capturing grazing, resting/ruminating behaviour, but further work is required to calibrate and maximise the activity sensors fitted to the GPS collars.
- On-going work of a similar nature will produce more comprehensive data sets appropriate for a variety of land-types, given that sufficient supporting GIS information exists.
- Selection of paddock scale and consideration of prevailing climatic conditions will be crucial in generating data sets that quantify distinct patterns of patch and landscape selection.

Identifying biophysical determinants

- GIS layers can be used to identify biophysical determinants such as soil and dominant vegetation and define land-types in a relative spatially explicit manner.
- Three broad soil groups, 10 distinct land-types and 11 biophysical determinants were identified from soil and pasture surveys and independent GIS layers for the Wambiana study site
- Pasture yield and composition for six land-types were identified from paddock surveys and Landsat satellite imagery for a commercial sized paddock.
- At both the experimental and commercial scales, watering points were highly frequented areas and generally biased the relationship between animal location and other biophysical determinants.
- A catalogue of potentially relevant bio-physical determinants to suit paddock, property, regional scales, or targeted to address specific issues facing grazing management need to be generated as the first step to compile relevant GIS data sets for the northern beef industry.

Influences of paddock scale and commercial application

- Grazing animal distribution was influenced by the location of water and land-types at both the experimental and commercial scales.
- It was not possible to extrapolate relationships from one scale to another. At the Wambiana study site virtually all land types were occupied at some time because of limiting biomass

availability. In the commercial paddock differences in biomass availability was more defined and animals demonstrated a distinct preference for a specific land-type associated with improved pasture.

- As paddock scale increases to compliment commercial properties, larger data sets will be required to eliminate the biases generated by sampling only a small proportion of a herd where individual behaviour may influence spatial data sets.

<u>Using GPS technologies for management of large heterogeneous paddocks</u>

- The project has demonstrated the commercial application of GPS technologies in determining grazing animal distribution and movement in the sub tropical savannas.
- The drought conditions and atypical paddock design at the Wambiana site combined to make this study less than ideal for the evaluation of GPS units to determine grazing preferences of cattle.
- Changes to the functionality of the GPS collars such as a higher fix rate, increased duration of deployment and power supply will combine to improve the richness of the spatial data collected.
- As the functionality and reliability of the GPS devices improve so too will the integrity of the spatial data sets we collect to derive grazing distributions.
- Lessons learned from the commercial paddock and Wambiana deployments have been invaluable for the planning of future work using GPS and GIS technologies.
- Spatial relationships based on GPS derived positional data can be used to quantify our experience, reason or intuition.
- If data sets are to be used for modelling pasture utilisation or quantifying sustainable grazing practices relevant to northern Australia then on-going work of a similar nature will need to generate outcomes that are more precision based than those derived from local experience or stockman intuition.

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9. Appendices

Appendix 9.1 Background information

Table A9.1.1 Data fields recorded by BlueSky™ Telemetry GPS collars

Output	Description
Time : Date	Hr / min / sec : Day / month / year
Status	Success in locating a fix dependent on number of satellites available; *OK* if location is determined, *no position data* if <4 satellites are found in the allocated search period or *GPS receiver fault* if unit fails to operate.
Longitude/Latitude	Decimal degrees
Hor. Error/ Ver. Error	m. Horizontal dilution of precision (HDOP) and Vertical dilution of precision (VDOP) calculated by the GPS unit based on satellite geometry.
Height	m. Calculated using HDOP, VDOP with a Karman filter
Sat. number	Absolute number of satellites available to obtain a 2-Dimensional location
Temperature	ºC. Ambient temperature ± 0.1ºC, but not identical due to thermal inertia of the collar
Min/Max pitch tilt	Angular degrees ± 4º
Min/Max roll tilt	Angular degrees ± 4º

Table A9.1.2 Data collected by GPS units, mapping elements and data calculated to determine spatial and temporal measures relating to animal distribution

Datum	Dimension	Processed data
GPS Time : Date	temporal	Number of continuous 24 h periods, Diurnal patterns, discrete hourly and daily time periods, Total number of days operational
GPS Status	temporal	Success in locating a fix, dependent on number of satellites available. Effective duration of deployment derived from GPS functionality, proportion of satellite fixes, GPS errors or no fixes, number of continuous 24 h periods
GPS Longitude/Latitude	spatial	Positional data for individual animals, animal distribution for each period, distances travelled per time, distance travelled between visits to water, extent of MCP, location identifier for 25 x 25 m cells, proportion of animal positions by land-type
Bio-physical determinants	spatial	Dominant vegetation and soils, NDVI, tree cover data. Total area (ha) available, proportion of available land-types, unique identifiers for each 25 x 25 m cell

Table A9.1.3 Paddock allocation, paddock size, number of continuous 24 h blocks, mean distances travelled per day and 95% MCP for cattle fitted with GPS units, deployments 1 to 4 Wambiana study site.

Stocking rate	Paddock No.	Paddock (ha)	Collar No.	No. of 24 h blocks	Distance (m / 24h)	MCP (ha)
			Deployment 1 (October 2004)			
Heavy	4	92	5	16	7545	80
			23	3	7293	68
			25	0	-	85
	9	103	10	13	3649	86
			19	7	4203	101
			26	10	4192	83
Light	5	114	9	3	4810	88
			18	4	4776	96
			21	1	4533	91
	7	115	22	0	-	98
			49	1	5488	97
			50	6	4676	97
			Deployment 2 (February 2005)			
Heavy	4	92	5	7	4544	86
			25	0	-	-
	9	103	10	10	7228	96
			19	4	6770	92
			26	24	6101	102
Light	5	114	18	0	-	112
	7	115	49	5	6658	108
			Deployment 3 (November 2005)			
Heavy	4	92	5	0	-	73
			26	2	6490	81
	9	103	21	2	6186	69
			22	7	6300	91
			170	1	8817	57
Light	5	114	23	21	5695	109
			85	1	5208	91
	7	115	10	24	6296	108
			18	0	-	73
			19	6	5252	93
			Deployment 4 (February 2006)			
Heavy	4	92	19	0	-	87
Light	5	114	5	10	6191	108
			183	0	-	-
	7	115	26	0	-	110

Appendix 9.2 Technical challenges and development

GPS unit performance

Paddock allocation, fix rate and GPS performance rate (%) for deployments 1 to 4 at Wambiana are shown in Table A9.2.1. Performance rate for individual GPS units ranged from 0.4 to 94%. Performance was calculated as the proportion of GPS locations obtained for the duration of that deployment. This calculation does not take into account times when the GPS unit operated, but could not determine a position. We assumed that for a fix rate of 1/h or 2/h, 24 or 48 fixes were possible every day, respectively. By example if a collar was deployed for 35 d at a fix rate of 30 min (2/h), 1680 (35 x 24 x 2) GPS positions would be expected. However, if the collar only functioned for 25 d of a 35 d deployment and obtained only 1168 positions then the performance of this collar would be 1168/1680, or 69.5%. All units were successfully reprogrammed and regarded as fully functional prior to each deployment.

GPS unit performance between deployments was assessed using GenStat® (V8.2, 2005). There were no significant differences ($P>0.05$) in the number of actual GPS positions obtained given the number of days operational, recorded GPS faults or number of continuous 24 h periods obtained between deployments. However, there were significantly more days when GPS units were operational for deployments 1 (29.6 d) and 2 (25.7 d), compared to deployments 3 (11.2) and 4 (9.3). The performance of the GPS units in the last two deployments at Wambiana was less than satisfactory. The number of locations that can be collected is generally dependent on the tracking schedule, configuration of satellites and their visibility to the GPS antenna (BlueSky Telemetry™ Ltd). Cloud and dense canopy cover would also contribute to inconsistent performance of these GPS units, but were not identified as the principal causes of the poor performance observed here.

The major contributing factor to the decrease in collar performance was associated with the ongoing failure of batteries under extreme temperatures. Maximum daily temperatures in excess of 36 ºC were common during the wet season deployments. The use of standard alkaline batteries and “thermal runaway”, where the operating temperature of the battery is exceeded as heat generated by the battery itself is augmented by the ambient temperature, resulted in the eventual internal corrosion of the GPS units.

Table A9.2.1 Paddock allocation, days of deployment, days GPS units functioned and positions obtained, fix rate and mean paddock performance rate for GPS units (%), deployments 1 to 4, Wambiana

[1]Duration of deployment, [2]Number of days GPS unit functioned, [3]fix rate per hour; 1=per hour, 2=every 30

Stocking rate	Paddock No.	Collar	Deployment (d)[1]	Operational (d)[2]	Fix rate (/h)[3]	Actual GPS positions[4]	Performance (%)[5]	Mean performance (% / paddock)
				Deployment 1 (October 2004)				
Heavy	4	5	35	34.5	1	796	94.8	
		23	35	5.6	1	128	15.2	
		25	35	34.5	1	384	45.7	52
	9	10	35	32.5	1	739	88.0	
		19	35	32.2	1	321	38.2	
		26	35	32.5	1	719	85.6	71
Light	5	9	35	30.8	1	473	56.3	
		18	35	34.5	1	705	83.9	
		21	35	20.5	1	364	43.3	61
	7	22	35	32.5	1	397	47.3	
		49	35	32.5	1	481	57.3	
		50	35	32.5	1	385	45.8	50
				Deployment 2 (February 2005)				
Heavy	4	5	50	38.5	1	413	34.4	
		25	50	30.4	1	5	0.4	17.4
	9	10	50	43.3	1	941	78.4	
		19	50	7.3	1	171	14.3	
		26	50	49.5	1	1112	92.7	62
Light	5	18	50	49.5	1	972	81.0	81
	7	49	50	38.4	1	836	69.7	70
				Deployment 3 (November 2005)				
Heavy	4	5	41	1.2	2	47	2.4	
		26	41	6.1	2	246	12.5	7
	9	21	41	15.4	2	199	10.1	
		22	41	18.1	2	620	31.5	
		170	41	1.0	2	37	1.9	14
Light	5	23	41	23	2	1053	53.5	
		85	41	1.3	2	60	3.0	28
	7	10	41	37.8	2	1539	78.2	
		18	41	1.7	2	59	3.0	
		19	41	7.1	2	335	17	33
				Deployment 4 (February 2006)				
Heavy	4	19	36	19.2	2	178	10.3	10.3
Light	5	5	36	35.2	2	1239	71.7	
		183	36	9.4	2	102	5.9	39
	7	26	36	29.3	2	421	24.4	24

min, [4]Actual number of GPS positions obtained from a minimum of 4 satellites for days deployed,
[5]Performance = [(No. GPS positions obtained)/deployment x 24 x fix rate] x 100.

Each unit was disassembled, decontaminated and tested after February 2005 in preparation for subsequent deployments. High temperature tolerant batteries (E2 Energizer® lithium batteries) were also used. Nevertheless, inherent corrosion compromised the integrity of the circuit boards to such an extent that data from several units could not be retrieved after the final deployment at Wambiana.

Performance of GPS units in the field under extreme conditions for extended periods could not be guaranteed regardless of successfully programming each GPS unit prior to use. High temperature tolerant lithium AA batteries were used to power the GPS units in the commercial study. However, GPS performance in the field was less than satisfactory with only seven of the 12 units providing sufficient data for spatial analysis of distribution and animal movement. Only 44 d of GPS data was collected despite manufacturer specifications (BlueSky Telemetry™ Ltd) indicating that 119 to 397 days could be expected with a fix rate of 48 positions per day. Problems with battery discharge and variable success in obtaining a GPS position from more than four satellites were identified as potential causes for less than satisfactory functionality.
Residual corrosion within the GPS circuit board itself was identified as the principal cause of poor functionality.

Fix rates for obtaining positional data

Straight-line paths were assumed between successive GPS positions. However, distances travelled by individual animals were likely to have been underestimated.

GPS fix rate was set to 30 min intervals (2 / h) for deployments 3 and 4 compared to the fix rate of 1 / h used in deployments 1 and 2. This schedule was implemented to provide a more robust data set by allowing for a more realistic measure of distances travelled during a 24 h period. There is an obvious relationship between fix rate and distances travelled for 24 h (Figure A9.2.1). As fix rate is increased, sampling is intensified and a more accurate measure of distances travelled by individual animals is obtained. To facilitate the calculation of Euclidean distances it is assumed that an animal travels in a straight line between GPS positions. This does not necessarily happen. Increasing the sampling frequency increases the amount of positional data collected and therefore better reflects true animal movement. However, it also increases the power demand of the unit and shortens battery life. It has been calculated that for every six additional fixes per day, the duration of a deployment may be reduced by approximately 7%.

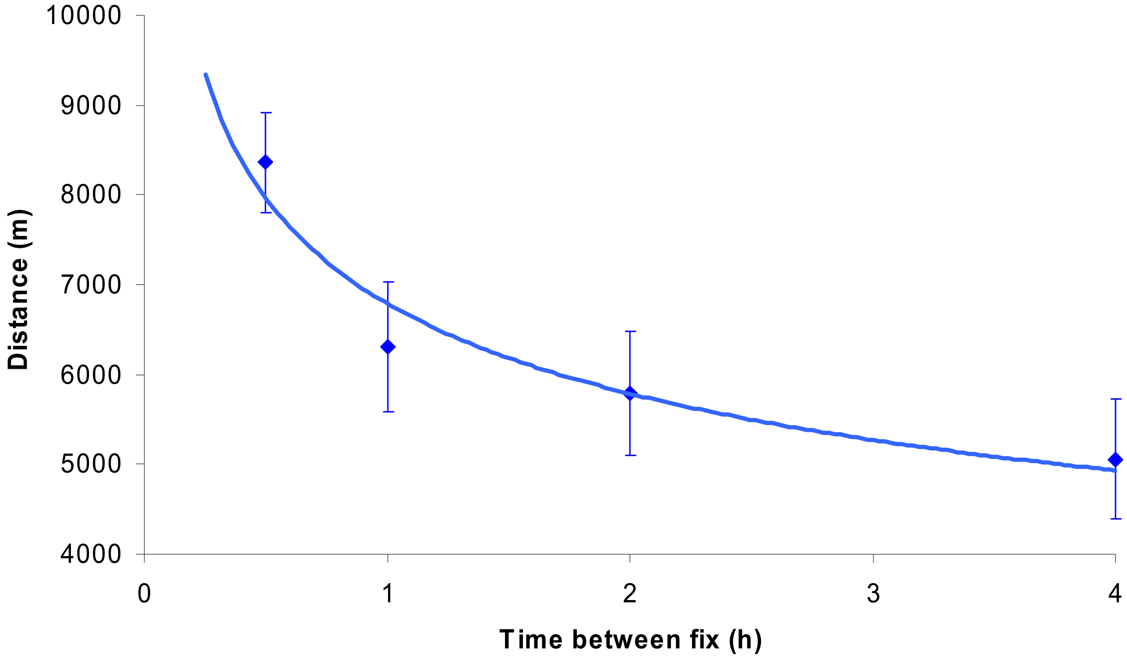

Figure A9.2.1. Relationship (y = $6789x^{-0.23}$, R^2 = 0.93) between GPS fix rate and the calculated mean (± sem) distance travelled per day for grazing cattle. The data are derived from the sum of the distances from 0.5, 1.0, 2.0 or 4.0 hourly fixes obtained in deployment 3 (n = 7).

Solutions and advances

High temperature tolerant AA lithium batteries are now being used in the GPS units to manage "thermal runaway" and reduce the possibility of internal corrosion compromising functionality of the GPS units. In an unrelated study these batteries have performed satisfactorily.

The GPS units are now supplied in moulded poly-carbonate housing. This has resulted in a reduction in weight and it is anticipated that the change in housing material will also assist in dissipating battery and ambient temperature loads.

Fix interval for determining a GPS position has been reduced from 60 to 30 minutes (1 to 2 / h, respectively). It is expected that a further reduction to 20 minutes (3 / h) will increase the accuracy of calculating distances travelled by the animal. Further investigations will confirm the relationship described in Figure A9.2.1 and determine if the increase in accuracy for calculated distances is statistically significant.

Specific software is now available and developed to such an extent that its use will maximise the value of grazing livestock GPS data and interpretation when used in conjunction with relevant GIS layers. The Home Range Extension (Home Range Tools) for ArcGIS (Ver 9.2 ESRI, Aust) has been assessed for applicability to the current project, but was not used. A programme designed to analyse movement paths of animals, Fractal V5.05 (NSCA, 2006) is now available, but is yet to be assessed using the spatial date sets collected in this project.

General comments

It is only since the commercial development of GPS for tracking animals (Rodgers 2001) that a relatively reliable and easy method to monitor landscape selection has emerged. However, to fit or retrieve GPS units to cattle additional musters, compared with normal property practices, are required. Although remote drop off units are available, they are expensive, increase overall collar weight and size, have a single use capability and can not guarantee 100 % recovery of all units.

Other GPS units, (CellTrax BlueSky Telemetry™ Ltd) have inbuilt functionality allowing for programming and data download using GSM phone and UHF radio link. However, these units are costly and there is some uncertainty as to the functional life of the devices in terms of power when archived GPS data are downloaded intermittently.

GPS devices and GIS software can be used to quantify grazing distribution and land-type associations. This approach is becoming more common in developing sustainable land management strategies (Wade *et al*. 1998; Parsons *et al*. 2001). However, the cost of GPS units continues to be prohibitive for large scale, statistically robust studies and a considerable time and labour input is still required to fit or recover the devices. Further use of GPS technology for grazing animal tracking will be limited by;

1) *Cost of "off the shelf" technologies*. Currently there are no Australian manufacturers of similar devices and CSIRO Livestock Industries do not have the capacity to generate specific equipment for GPS tracking of cattle under extensive conditions.
2) *Power management*. Improved battery technology or alternative power sources are required for extended studies under extreme conditions, particularly where mustering is less frequent. Solar or impedance devices are possible, but would require specific and dedicated research efforts beyond the scope of CSIRO Livestock Industries.
3) *Design*. Further advances in unit design are required to reduce dust and moisture entry that would compromise functionality. Isolating corrosion at the source and reducing thermal inductance are also challenges for manufacturers of these devices.
4) *Data acquisition and interpretation*. Large data sets on grazing animal behaviour will need to be generated for stochastic modelling of grazing behaviour if relationships between environmental variables, typical of northern Australia's spatially heterogenous landscapes, are to be fully understood.

Appendix 9.3 Land-type association by Brahman cross steers, Wambiana study site

Table A9.3.1 Proportion of land-type and number* of animal GPS locations in each land-type for Wambiana study site.
*Total counts of individual animals for (*n*) deployments

			Soil / vegetation land-type									
			Coolibah	Black Clay	Ironbark	Box annuals	Box Brigalow	Box Eremophila	Wet box	Box	Ironbark Ridge	Box Blackbutt	TOTAL
Available proportion			0.01	0.18	0.22	0.01	0	0.05	0.02	0.46	0.04	0.01	
	Heavy stocking												
		n											
Association with land-type by animal	1	*3*	0	44	48	0	0	180	217	290	46	5	830
	2	*3*	0	22	23	0	0	113	165	145	13	0	481
	3	*3*	52	135	338	82	0	37	0	279	0	0	923
	4	*3*	152	253	319	109	0	101	0	503	0	0	1437
	5	*2*	167	272	353	130	0	86	0	495	0	0	1503
	6	*1*	5	25	90	16	0	15	0	9	0	0	160
	7	*1*	0	3	5	0	0	25	30	23	4	2	92
		Σ	376	754	1176	337	0	557	412	1744	63	7	5426
Available proportion			0	0.16	0.21	0	0.04	0.11	0.01	0.46	0	0.02	
	Light stocking												
		n											
Association with land-type by animal	1	*3*	0	437	548	0	141	124	8	1156	0	0	2414
	2	*2*	0	126	19	0	7	9	1	224	0	0	386
	3	*1*	0	59	46	0	17	16	3	251	0	1	393
	4	*2*	0	275	247	0	8	70	0	572	0	9	1181
	5	*2*	0	142	85	0	11	33	0	358	0	4	633
	6	*1*	0	319	227	0	43	96	0	636	0	15	1336
		Σ	0	1358	1172	0	227	348	12	3197	0	29	6343

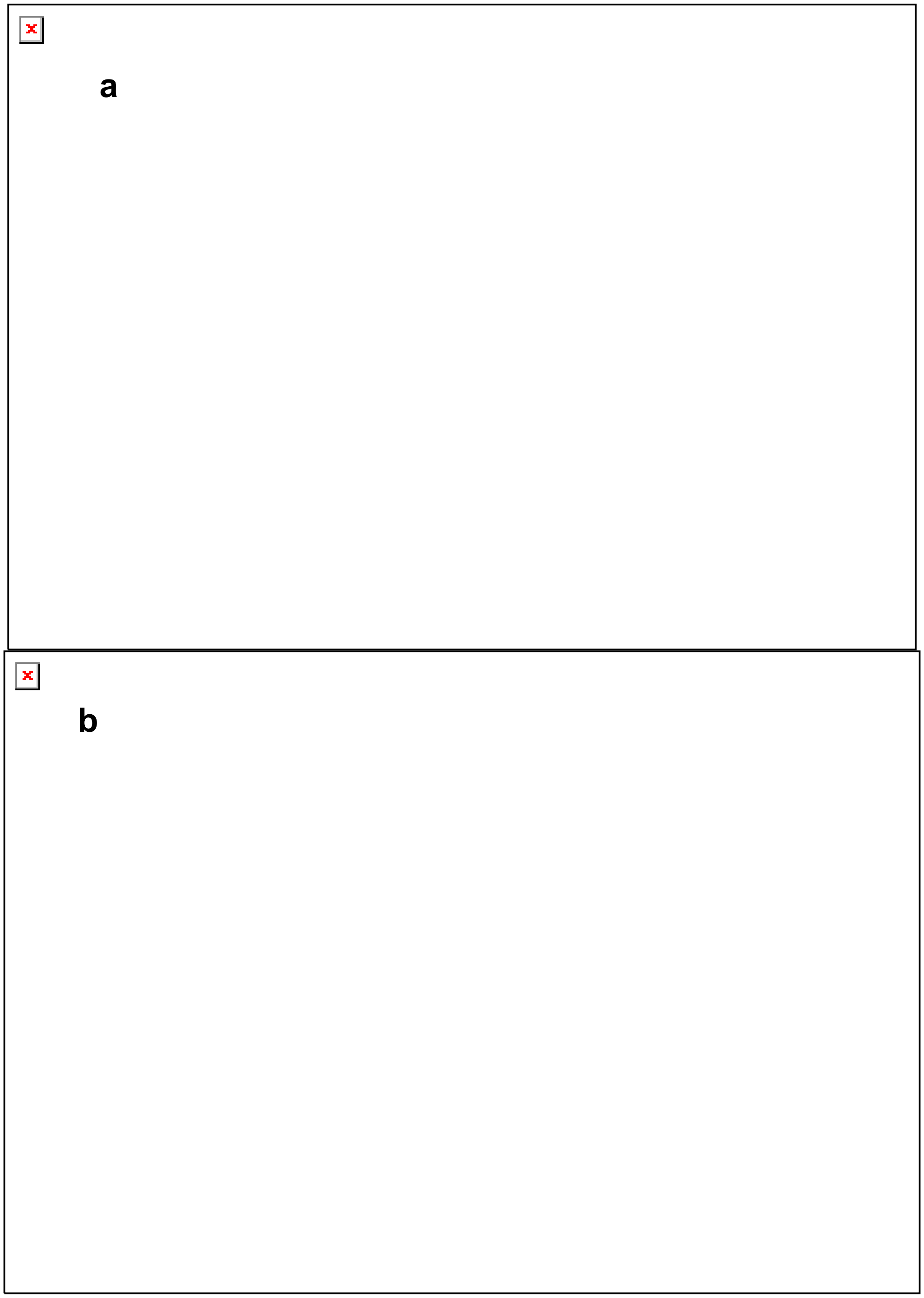

Figure A9.3.1 The distribution of Brahman cross steers fitted with GPS collars at the Wambiana study site, based on daily activity patterns **a)** resting/ruminating 22:00-05:00 h,
b) grazing/walking 05:00-10:00 h. Water points shown as (▲)

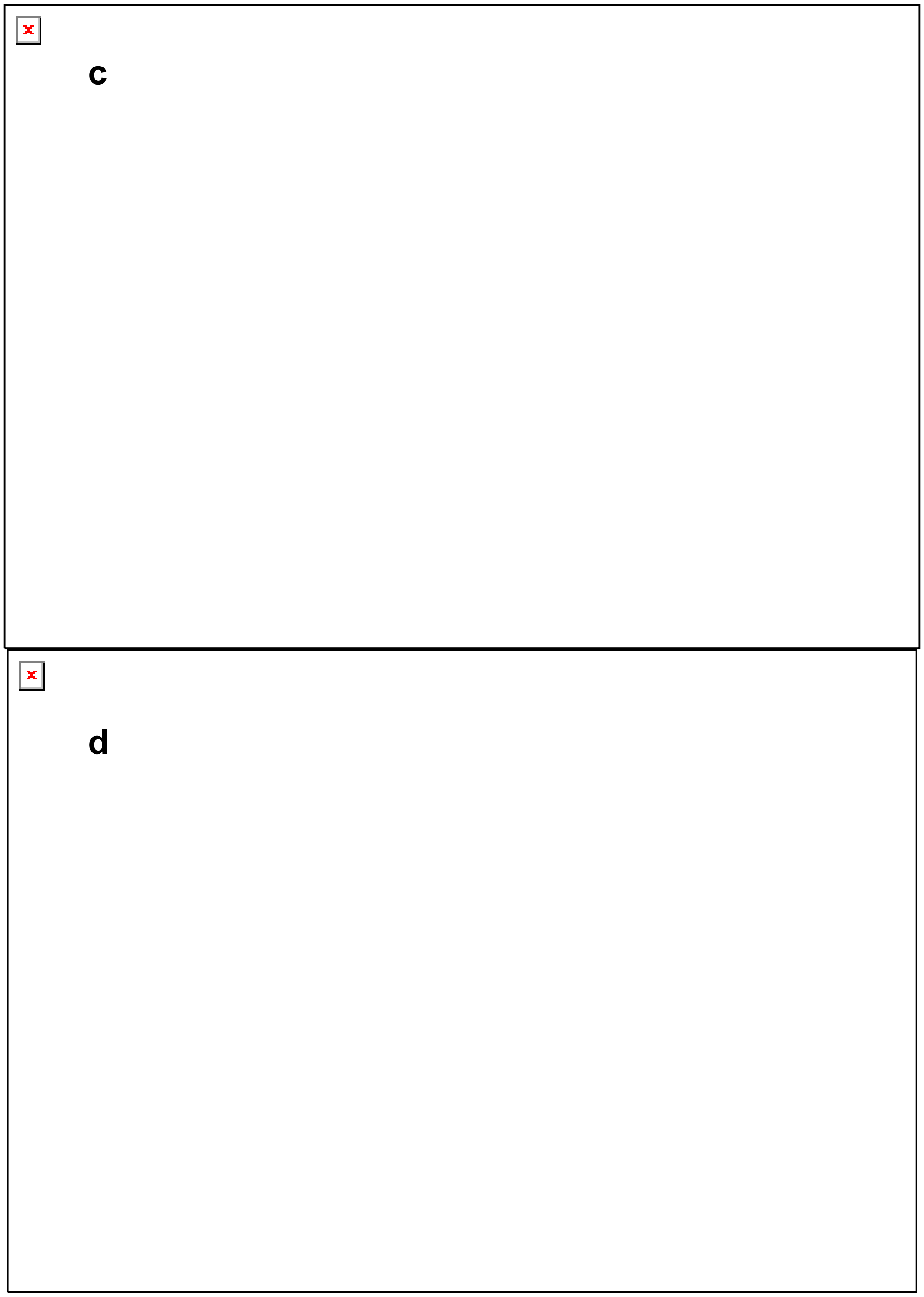

Figure A9.3.1 continued The distribution of Brahman cross steers fitted with GPS collars at the Wambiana study site, based on daily activity patterns **c)** resting/ruminating 10:00-14:00 h, and **d)** grazing/walking 14:00-22:00 h. Water points shown as (▲)

Appendix 9.4 Bio-physical determinants for grazing cattle

Spatial bio-physical determinants must be identified and placed into a hierarchy designed to incorporate multi-scale effects and selection indices. Consequently, a combination of determinants will be unique to each region, property or study site.

The extent of information at each scale may vary considerably. The following lists bio-physical determinants that may be relevant to grazing cattle;

Topography
Slope and elevation
Geomorphology
Soil type
Soil fertility / nutrient status
Soil condition (inc salinity)
Land-type
Artificial and natural water sources
Fence lines

Rainfall
Tree cover (SLATS)
NDVI (greenness index)
Pasture species
Fires/ fire scalds
Ground cover
Pasture biomass
Native flora and fauna
Competitive herbivory

Appendix 9.5 Communications and publications

Bishop-Hurley, G, Swain, D and O'Reagain, P (2005) Quantifying landscape selection by cattle under different management strategies in northern tropical savannahs. Aust. Soc. Anim. Prod. CQ sub branch mini conference. Darumbal Convention Centre Rockhampton Qld. 15-16.

Anon (2005) GPS collars track herds. Queensland Country Life December 8.

Anon (2005) Tracking to boost sustainability. Farm Weekly December 15.

Anon (2006) GPS to boost grazing sustainability. Farming Ahead February No. 169

Anon (2006) GPS keeps track of cattle's habits. North Queensland Register November 16.

Tomkins, NW, Charmley, E and O'Reagain, PJ (2006) Determining animal movement under different stocking rates in the tropical savannahs. *In* Proceedings 26th Biennial Conference of the Australian Society of Animal Production. Perth WA.

Tomkins, NW and O'Reagain, PJ (2006) Global positioning systems indicate landscape selection by cattle in the tropical savannahs. *In* Proceedings 14th Biennial Conference of the Australian Rangeland Society. Renmark SA.

Tomkins, NW and O'Reagain, PJ (2007) Global positioning systems indicate landscape association by cattle in the tropical savannas. (Invited paper), The Rangelands Journal – submitted.

Tomkins, NW, Charmley, E. and Williams, S (2007) Using global positioning systems to quantify landscape association by grazing cattle in northern Australia. In Proceedings Northern beef research Update Conference. Townsville QLD.

Tomkins, NW, Media release "Seeking greener pastures". An article generated from discussions with Roger Landsberg after the commercial deployment on Trafalgar Station. The article has been reviewed by Peter O'Reagain QDPI&F, Roger Landsberg and forwarded to Manager Public Issues & Communication CLI for release in 2007.

Tomkins, NW and Filmer, M (2007) GPS tracking can help sustainability. Farming Ahead No. 185 pp 68-71.

Tomkins, NW (22/06/2007) Radio National "Bush Telegraph" Using GPS to manage grazing cattle.

Tomkins, NW, Charmley E, O'Reagain, PJ and Swain DL (2007) Determining spatial grazing of cattle under different stocking rates in the sub-tropical savannas - In preparation.

MEDIA MONITORS
INCISIVE INSIGHT

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15/12/2005
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Published: ---T---

Tracking to boost sustainability

STATE-OF-THE-ART satellite technology is about to help northern beef producers improve land management and ensure long-term sustainability by better understanding cattle grazing behaviour.

Using collars on cattle fitted with global positioning system (GPS) radio telemetry, scientists from the CSIRO and Department of Primary Industries and Fisheries Queensland (DPIF) are using satellites to track the movement of cattle in the bush.

The aim of this new collaborative research project - conducted at Wambiana station, 60km south-east of Charters Towers - is to explain why cattle select some soil types and not others and how stocking rates affect this selection process.

The project on grazing selectivity adds value to a major grazing trial co-funded by DPIF and Meat and Livestock Australia (MLA) at Wambiana.

Cattle selectively graze different parts of the landscape, leading to overuse and degradation of particular areas and a reduction in the land's long-term carrying capacity.

CSIRO livestock industries spokesman Dave Swain said the GPS collars would enable scientists to remotely track the movement of cattle without handling them.

"The collars are placed around the animal's neck, automatically logging its position to within five or 10m every hour," Dr Swain said.

"Monitoring where cattle are spending the majority of their time grazing will identify the particular soils they are attracted to and enable us to predict where they will graze in a large paddock."

The project at the Wambiana site is part of a long-term DPIF grazing trial established in 1997.

DPIF spokesman Peter O'Reagain said extremely detailed biophysical data including soil type, soil fertility and pasture composition, was being collected at Wambiana.

"This data, together with other complementary research, will be of enormous benefit to this project," Dr O'Reagain said.

"The results from the study will increase our understanding of grazing behaviour and assist producers in predicting where the heaviest grazing will occur."

Co-funded by MLA's Northern Beef Program, the project is designed to develop new grazing strategies to ensure the long-term ecological sustainability and economic viability of northern savannas grazing.

The starch from ordinary wheat plants can be used to produce biodegradable plastics with similar properties to conventional plastics.

Plastics from wheat starch

CSIRO has created a new type of plastic derived from wheat.

Devised by CSIRO's Malcolm Jenkins and the CRC for International Food Manufacture and Packaging Science, the plastic offers a promising new market for wheat.

Not only does the biodegradable plastic break down quickly when discarded, it is made from Australia's biggest cereal crop and it won't contaminate any food it holds.

The new plastic has similar properties to conventional plastic.

The wheat starch is mixed with other ingredients then heated and stretched into long spaghetti-like rods before being broken into pellets.

The pellets are then forced out through a ring-shaped hole to form a tube, which is inflated with air to the required size.

This material is durable when on the shelf, but will disappear within 40-50 days after it is composted.

Dr Jenkins said it was conceivable that people could eat wrappers made from the new plastic after first consuming the product the wrappers contained.

Contact: Everand Hunder
Phone: (03) 9252 6439
Fax: (03) 9252 6400
Everand.Hunder@csiro.au

GPS to boost grazing sustainability

State-of-the-art GPS satellite technology will help northern beef producers improve land management and ensure long-term sustainability.

Using cattle collars fitted with global positioning system (GPS) radio telemetry, CSIRO and the Department of Primary Industries and Fisheries Queensland (DPIF) are using satellites to track the movement of cattle in the bush.

The aim is to find out why cattle select some soil types and not others and how stocking rates affect this selection process.

Cattle selectively graze different parts of the landscape, leading to overuse and degradation of particular areas and a reduction in the land's long-term carrying capacity.

The GPS collars are placed around the animal's neck, automatically logging its position to within 5-10 metres every hour.

Monitoring where cattle are spending most of their time will identify soils they are attracted to, enabling predictions of where they will graze in a large paddock.

This in turn will result in increased understanding of grazing behaviour and assist producers in predicting where the heaviest grazing will occur.

The project is part of a long-term DPIF grazing trial, established during 1997 and is co-funded by MLA's Northern Beef Programme.

Contact: Ed Charmley
Phone: (07) 4923 8174
Fax: (07) 4923 8222
Ed.Charmley@csiro.au

GPS collars are being used on cattle such as these in a bid to track grazing preferences and better understand grazing behaviour over large areas.

Microalgae crops in the pipeline

Oil-rich marine microalgae are being assessed for their commercial potential as an omega-3 oil-producing crop.

CSIRO and Clover Corporation are evaluating market opportunities for microalgae in terms of applications in animal or aquaculture feed, and as a refined source of beneficial docosahexaenoic acid (DHA) oil for human consumption.

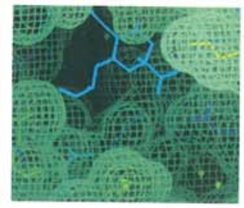
CSIRO recently isolated the microalgae strains which are now being trialled. In the laboratory the microalgae proved to be efficient producers of both DHA and eicosapentaenoic acid (EPA), both omega-3 oils.

The challenge is now to scale up microalgae production to large-scale culture vessels while maintaining the beneficial oil profile and production efficiency.

This entails moving from laboratory-scale cultures of 100 millilitres to pilot-scale cultures of 10,000 litres.

Omega-3 oils are important in infant nutrition, and beneficial against a range of human disorders including coronary heart disease, rheumatoid arthritis and hypertension.

Contact: Sylvia Bell
Phone: (02) 9490 8006
Fax: (02) 9490 8811
Sylvia.Bell@csiro.au



Genes matter in seed size

CSIRO researchers have discovered two genes which control the size of plant seeds and are investigating how this knowledge can be used to produce larger seeds across a wide range of crops.

In initial tests, where the genes were 'turned down', seed size was reduced by up to 30 per cent.

The challenge for the CSIRO team, led by Abed Chaudhury and Ming Luo, is to 'turn up' the activity of these two genes to increase seed size.

In certain crops, especially wheat and canola, large seeds mean more food for the seedling, early germination and vigorous plants, which are more likely to produce higher yields and subsequently potentially higher returns.

Plant breeders have long recognised the importance of larger seeds in the production of food crops and have been breeding for the trait.

Food like bread, pasta, rice, cornflakes, peanut butter, canola oil, margarine, soymilk and even coffee and chocolate are all made from seeds. Manufacturers and industry often pay a premium for large seeds such as chickpeas or lentils because they are easier to handle and are often preferred by consumers.

The two genes have been isolated in the model plant *Arabidopsis*, but are likely to have equivalent counterparts in other plants.

The team are also investigating a third gene which could help control the first two genes.

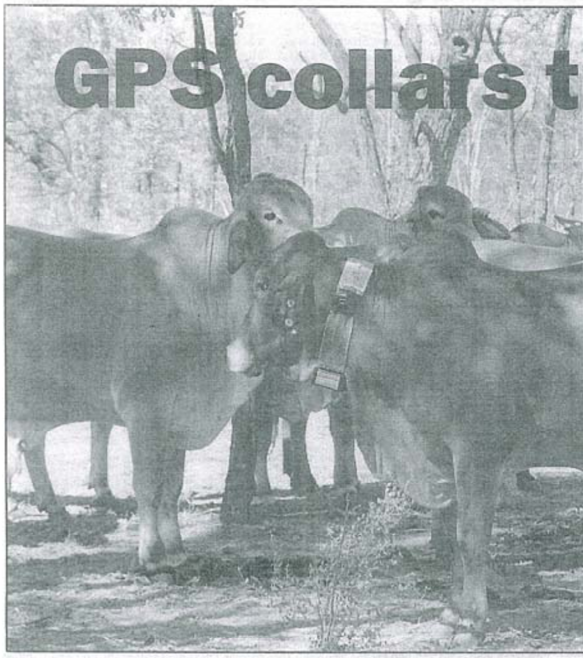
Contact: Abed Chaudhury
Phone: (02) 6246 5237
Fax: (02) 6246 5000
Abdul.Chaudhury@csiro.au

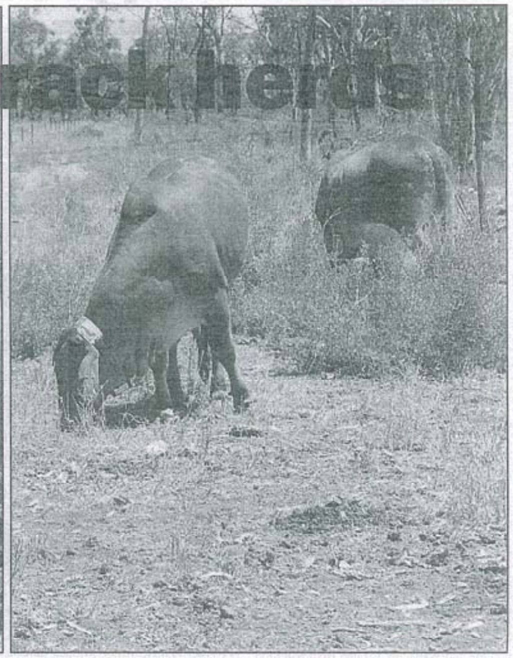
CSIRO

Livestock

Tropical sale, p102
Beef awards, p103
Charolais sale, p104

GPS collars track herds





CSIRO scientists are using satellite technology to track the grazing habits of individual cattle in an effort to ensure the long-term sustainability and economic viability of the beef industry in northern Australia.

The project is a partnership between CSIRO Livestock Industries and the Queensland Department of Primary Industries and Fisheries (DPI&F).

Co-funded by Meat and Livestock Australia's Northern Beef Program, the project is using specially designed Global Positioning System (GPS) collars to track the movement of individual steers.

CSIRO project leader Dr Dave Swain said cattle tended to graze selectively on different sections of the landscape, leading to overuse and degradation of particular areas.

He said little was known as to why certain areas were favoured over others.

Observing the cattle remotely via GPS collars would help provide information on selective grazing and stocking rates.

"The cattle have been fitted with GPS collars that automatically log their position in the paddock every hour," Dr Swain said.

"By monitoring their movements and tracking their positions to within a few metres we will be able to determine where they are spending the largest part of their time and where they are spending keys parts of the day."

The information will enable scientists to predict how cattle would graze in a larger paddock and is expected to lead to the development of grazing strategies to enhance production and sustainable land use. Dr Swain said most commercial paddocks in northern Australia were large, unevenly watered and contained a mixture of soil types and foraging material.

AT A GLANCE

- Scientists are using satellite technology to track the grazing habits of individual cattle.
- Cattle tend to graze selectively, leading to overuse and degradation of the landscape.
- The project is a partnership between CSIRO Livestock Industries and DPI&F.

As a result, cattle tended to use certain areas of a paddock and leave others.

"This uneven utilisation results in a reduction in productive capacity, increased soil erosion and loss of biodiversity in over-grazed areas," Dr Swain said.

"Ultimately, our big picture goal is to try and manage these sorts of environments with a little bit more precision.

"If we, for example, know that water is a very important attractant, we can then try to manage the grazing resource to avoid certain areas being overgrazed through strategies such as moving the watering points.

"It is about understanding what is driving the cattle. If we can understand that then we can construct systems that maximise the spatial availability of the resources."

So far 12 cattle have been fitted with the special collars.

Animal locations are recorded hourly for six-week periods during the wet and dry seasons.

Data from the collars is downloaded during routine musters of the animals. Dr Swain said the trials were using two different stocking rates in a bid to work out whether there were differences in behaviour and time spent grazing at different levels of stocking.

"For example, if the animals are spending a lot more time in the high stocking rates searching for food, then that clearly will take them a lot more energy and potentially it could be reducing the time they spend resting in shade during the hottest part of the day or at a watering point," he said. "These factors could have production implications."

The research is taking place at Wambiana Station, 60 kilometres southeast of Charters Towers and is part of a long-term DPI&F grazing trail established in 1997.

DPI&F rangelands scientist Dr Peter O'Reagain said the latest project would build on and add value to the long-term trial.

"The main grazing trial at the Wambiana Station is looking at different ways of managing for rainfall variability with cattle and specifically managing stocking rates in relation to the varying seasons," Dr O'Reagain said.

"The project with the collars will look at where cattle graze in the landscape.

"It will show us how stocking rates affect grazing behaviour, how far the cattle move during the day looking for food and how long they spend grazing." Dr O'Reagain said paddocks used in the trials had already been extensively surveyed and maps developed that detailed soil types and features.

Data from the collars when overlayed on the existing maps would provide information that, would give a detailed picture as to what areas the cattle preferred and why.

Dr Swain said the project was the first time that detailed information had been collected on the grazing habits of cattle.

NQ Register Thurs 16/11/06.

BEEF

Why Wambiana got nod


Picture: Kate O'Donnell

WAMBIANA was eventually chosen as the trial site for a DPI&F-MLA grazing trial because it had a guaranteed water supply and a good mix of land types.

Owners John and Ronda Lyons, pictured, were interested in the project from the start and keen to see the results of the research.

"I knew we had gone from one era to another (in grazing) and we needed another management system," Mr Lyons said.

"The old management system had got us to this stage, but it's not good enough to take us to the next stage."

Mr Lyons believes that changes in grazing practice over the past few decades mean that for the first time the grazier is in a position to damage the land, especially through overstocking.

"We had the capacity to really hurt the land for the first time ever through having too many animals because of supplements like urea and molasses," he said.

"I really wanted to see the outcome of the stocking rate trials, and some of the newer methods like SOI and rotational spelling."

Peter O'Reagain says the close involvement of graziers with the project since its inception is relatively unusual. A grazier advisory committee was established in 1997 and has played a major role in many aspects of the trial's management. For example, the stocking rates applied at the trial are largely based on the advisory committee's advice on appropriate stocking rates for the different land types at the site.

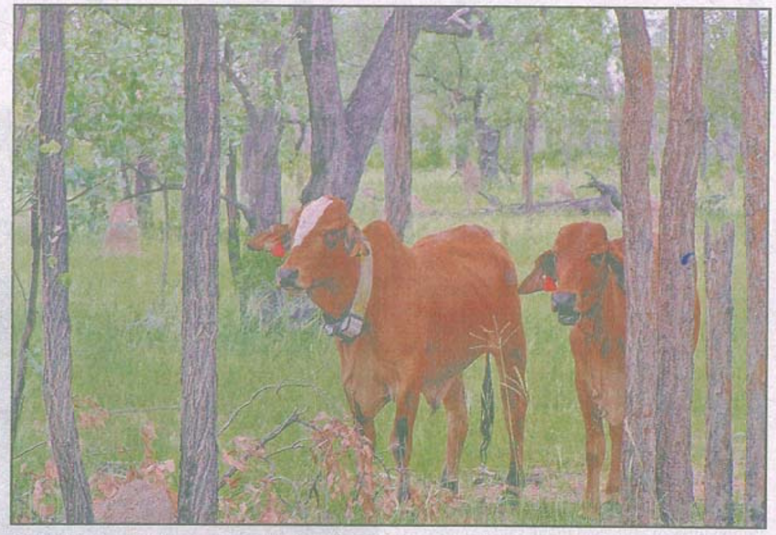
"Grazier participation has been critical to maximise relevance to the industry and the potential adoption of project outcomes," Mr O'Reagain said. "This has also encouraged discussion and debate and is something from which all of us can learn a lot."

One of the project aims was to put 'facts and figures' on existing management techniques - to get a better understanding of what many graziers already do. "We've never had the numbers," Mr Lyons said.

"You can tell a good story in this game, because no one can pull you apart. It's full of motherhood statements, old stories, nostalgia and tradition - but the industry is now becoming factual."

After eight years and a range of seasons, everyone associated with the project is still keen for it to continue.

"Everything in the bush happens on a 30-year cycle; it's slow out here," Mr Lyons said. "I would like it to continue for 40 years."


Cattle fitted with GPS collars are allowing scientists to track their movement, and thus map their grazing habits. Picture: Peter O'Reagain.

GPS keeps track of cattle's habits

COLLARS on cattle fitted with GPS are allowing CSIRO and DPI&F scientists to track the movement of cattle in the bush.

The aim of this collaborative research project, also conducted at Wambiana, is to discover why cattle select some soil types and not others, and how stocking rates affect this selection process.

CSIRO Livestock Industries scientist Ed Charmley says the devices allow the location of an animal to be captured every 30 minutes without affecting their normal behaviour.

"Studies with GPS-collared animals will also be important in evaluating the placement of additional water points, fences or other management strategies to manipulate grazing distributions on large, spatially variable paddocks," he said. The collars have also been used on Roger and Jenny Landsberg's property, Trafalgar, Charters Towers.

Scientists are now determining if there is any difference in the selective grazing habits between paddocks at Wambiana and a larger paddock at Trafalgar. Comparing the two paddock scales will allow scientists to find out if the spatial relationships between grazing animals and their environment can be scaled up to commercial-sized paddocks.

Co-funded by MLA's Northern Beef Program, the project is designed to help develop new grazing strategies to ensure the long-term ecological sustainability and economic viability of Northern savanna grazing.

DETERMINING ANIMAL MOVEMENT UNDER DIFFERENT STOCKING RATES IN THE SUB-TROPICAL SAVANNAHS.

N.W. TOMKINS[A], E. CHARMLEY[A] and P.J. O'REAGAIN[B]

[A]CSIRO Livestock Industries, JM Rendel Laboratory Rockhampton, Qld 4702.
[B]QDPI&F PO Box 976 Charters Towers, Qld 4820

The most important management factor determining resource condition and animal production in any grazing system is the stocking rate or utilisation rate of the available pasture (O'Reagain and Turner 1991). Consequently, a major challenge for animal production in the semi-arid tropical savannahs is the adoption of sustainable grazing practices. The location of water points has been identified as the primary determinant of landscape selection by grazing animals (O'Reagain 2001). The relationships between grazing and environmental drivers need to be identified to accurately predict the impact of alternative management regimes and grazing across diverse and fragile landscapes. The study reported here determined the distances animals were prepared to travel under two different stocking rates, using Global Positioning System (GPS), and is part of a larger project investigating patch grazing in the sub-tropical savannahs.

The study was conducted on Wambiana Station, near Charters Towers Qld. Paddocks of approximately 100 ha were used, each containing similar areas of three distinct land-types. Stocking rates were; light stocking (8 ha/ large stock unit [LSU equivalent to 450 kg Brahman cross steer]) and heavy stocking (4 ha/LSU). Treatments were replicated twice in a randomised block design. Three animals in each replicate were fitted with GPS units (BlueSky Telemetry Ltd) in October 2005. The GPS units were programmed to acquire a position every 30 min from a minimum of 4 satellites for a total period of six weeks to determine individual daily distances travelled and associated grazing patterns. Paddock surveys, using BOTANAL technique, and Landsat imagery were used to identify dominant vegetation types (*Eucalyptus brownii, E. melanophloia and Acacia ssp*. communities).

Based on GPS positions, distinct distances of travel over a 24 h period were apparent (Figure 1). Further interpretation of the data indicated that cattle would converge on water points in the morning and disperse during the late afternoon. Animals in the heavy stocked paddocks travelled a mean distance of 7.0 km per day, up to 1.5 km further compared to light stocked animals.

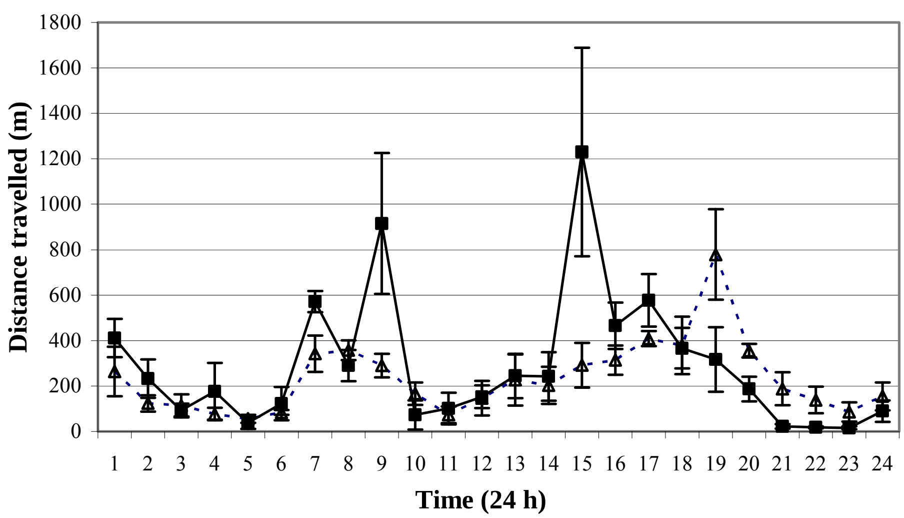


Figure 1. Mean (±sem) distance travelled over 24 h for light (△) and heavy (■) stocked animals

Animals in the heavy stocking groups also travelled, on average, up to 1 km further from a water point compared to lighter stocked animals throughout a 24 h period. In addition to the location of water, pasture availability and soil type across the experimental paddocks appeared to be important variables influencing cattle movement. Further analysis will determine spatial grazing patterns based on soil/dominant vegetation relationships and pasture availability. GPS animal locations will be presented at the conference. The quantitative understanding of animal movement across these heterogenous landscapes will assist in the formulation of alternative grazing management practices and the location of additional water points to facilitate sustainable pasture use across the sub-tropical savannahs.

O'REAGAIN, P. and TURNER, J. (1992). *J. Grass. Soc. SA.* **9:** 38-49.
O'REAGAIN, P. (2001). *Proc. XIX Int. Grass. Congress*: 277-284

Email: Nigel.Tomkins@csiro.au

In: Proceedings 26th Biennial Conference of the Australian Society of Animal Production. Perth WA.

GLOBAL POSITIONING SYSTEMS INDICATE LANDSCAPE SELECTION BY CATTLE IN TROPICAL SAVANNAS.

NW TOMKINS[1] & PJ O'REAGAIN[2]

Department of Primary Industries and Fisheries
Queensland Government

[1]CSIRO LIVESTOCK INDUSTRIES JM RENDEL LABORATORY PO BOX 5545 CQ MAIL CENTRE, QUEENSLAND 4702
[2]DEPARTMENT OF PRIMARY INDUSTRIES & FISHERIES PO BOX 976 CHARTERS TOWERS QUEENSLAND 4820

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Abstract

GPS collars were fitted to Brahman cows on a commercial property near Charters Towers Qld. The study area had a single water point and contained diverse land types. Grazing preferences were initially limited to a 250 ha cleared area of clay soil sown with Buffel grass (Cenchrus cilliaris). Thereafter, animals moved on to less fertile areas of Eucalyptus and Blackwood (Acacia argyrodendron) native pasture woodland. Animals avoided areas dominated by steep terrain and travelled a maximum of 4.1 km from water. The study confirmed that landscape selection of grazing cattle can be interpreted through GPS and satellite imagery.

Introduction

- Variable landscapes and the large scale of northern Australian beef properties provide challenges for sustainable management
- Understanding the main factors driving spatial selection by grazing cattle is required
- Foraging strategies determine the intensity, timing and spatial location of grazing pressure
- Grazing animals spend the greatest proportion of their time in areas offering the highest rate of nutrient intake
- Areas close to water and/or dominated by palatable species are selectively grazed
- GPS units provide a method to measure selection for different landscape units

Methodology

- BlueSky™ GPS collars fitted to 12 Brahman cows for 8 weeks
- Trafalgar Station, 60 km south-west of Charters Towers Queensland
- 1530 ha paddock, one water point and a mixture of land types
- Average annual rainfall 650 mm. Eastern sub-humid woodlands dominated by Northern box and Ironbark (Eucalyptus spp.) on undulating low hills
- Pasture yield and composition measured using BOTANAL along 6, 3-4 km transects

Results and Discussion

Peak periods of travel were confined to dawn and dusk which were probably the main grazing times (Figure 1). During these periods animals travelled up to 800 m in an hour. Mean distance travelled between visits to water was 13.8 ± 4.77 km. Some animals did not return to the water point for up to 3 d, but it is possible that small ephemeral waterholes were being used. Mean minimum convex polygon area was 341 ± 85.5 ha. Animals accessed a maximum of 671 ha or 44 % of the paddock. Areas dominated by steep stony terrain where avoided which would have limited the area of spatial selection (Figure 2).

Figure 1. Mean (±sem) distance travelled by Brahman cows.

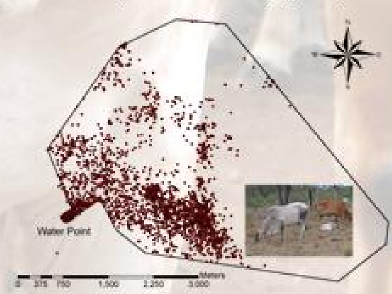

Figure 2. Grazing distribution of one animal over 8 weeks.

Grazing preferences were initially limited to 250 ha cleared area of clay soil sown with *C. cilliaris* and relatively close (≤ 4.1 km) to water. Animals then moved on to less fertile, outlying areas of *Eucalyptus* and *A. argyrodendron* native pasture woodland. Selective grazing by animals in certain areas can indicate the extent of landscape heterogeneity. Knowledge of pasture distribution and landscape selection by cattle can be useful in planning sustainable pasture management systems.

E-mail: nigel.tomkins@csiro.au

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USING GLOBAL POSITIONING SYSTEMS TO QUANTIFY LANDSCAPE ASSOCIATION BY GRAZING CATTLE IN NORTHERN AUSTRALIA

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MEAT & LIVESTOCK AUSTRALIA

NIGEL TOMKINS, ED CHARMLEY & SAM WILLIAMS

CSIRO

CSIRO LIVESTOCK INDUSTRIES, ROCKHAMPTON, QUEENSLAND, AUSTRALIA

Background

Estimating pasture utilisation across large heterogeneous paddocks (>1000 ha), typical of northern Australia, provides a major challenge for researchers and for the adoption of sustainable land management practices. Global positioning systems (GPS) for livestock provide a relatively reliable and easy method to quantify animal-landscape associations. Combining GPS data and geographic information systems (GIS) with spatially explicit models will be pivotal in developing sustainable land management strategies for northern Australia.

Introduction

- Fencing by land type can be uneconomical
- Grazing impact is driven by the quality and availability of forage
- Cattle select areas offering the greatest intake rate of digestible energy
- Intensity, timing and spatial location of grazing can be variable.

Research outputs

- ✓ Quantifying animal-landscape associations using GIS software and GPS units (Fig 1)
- ✓ Developing temporal relationships (Fig 2) based on animal activity
- ✓ Contributing to the development of management guidelines for sustainable pasture utilisation in northern Australia.

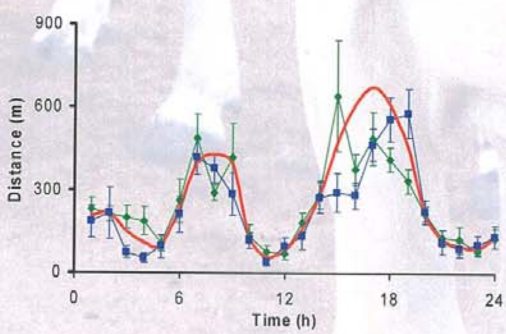

Figure 2. Similar patterns of travel per day between different stocking rates have been identified (♦4 ha/beast, ■ 8 ha/beast, - trend).

Scope

How can we quantify landscape association and pasture utilisation by cattle?

- GPS for livestock can be used to quantify animal-landscape associations
- Sufficiently large data sets on grazing animal distribution are needed
- Sustainable land management strategies for northern Australia can be developed.

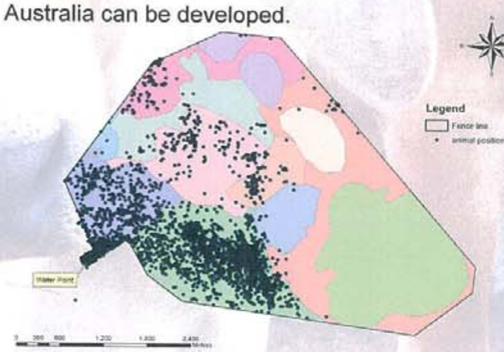

Figure 1. Grazing distribution of Brahman cows in a large (1530 ha) heterogeneous paddock near Charters Towers, Qld. Shaded areas indicate different land-types.

Opportunities & future research

Further work with GPS units on cattle and satellite imagery could evaluate the effect of placement of water points and alternative management strategies on grazing distribution in large heterogeneous paddocks. Identifying herd dynamics and seasonal variability will be future challenges for researchers. Conducting work on commercial properties is crucial to developing technologies immediately relevant to the northern beef industry.

E-mail: nigel.tomkins@csiro.au