final report

Northern Beef Program

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Understanding the dynamics of Queensland's grazed woodlands

Queensland Government
Department of Primary Industries and Fisheries

Abstract

On-ground monitoring of woodlands provides a baseline for discerning the general trend of woody vegetation change across the landscape and over time. Knowledge of woodland change can be used to stimulate proactive management to maintain and improve profitability and landscape function of woodlands used for grazing production and other land uses. Our project has continued and improved the TRAPS woodland monitoring network by developing more rigorous data handling systems and improving the ability to extract data efficiently from the newly developed 'DRYAD' database. Collaborative activities have ensured that the insights from the monitoring network have been utilised in the validation of regional-scale tree cover change assessments using aerial photography and satellite imagery and in modelling initiatives assessing the cause of woodland change and the potential impact of fire strategies for managing woodland vegetation.

Since 2004, 72 TRAPS sites (of 111) have been re-recorded and two new sites have been established. Analyses were conducted to demonstrate the functionality of the DRYAD database and provide an update on woodland trends. One analysis indicated that there are regional differences in woody vegetation response to the recent relatively dry period (1999-2005). The study area was split into south, central and north regions. In remnant ironbark sites, the' Eucalypt' population declined in the central region (-9%) while increasing in the south (7%) and north (7%) regions, meanwhile 'other woody species' increased (10-43%) across all regions. Another analysis investigated differences in vegetation response between the latest relatively dry period (1999-2005) and the previous 1985-1999 period. In ironbark woodlands the basal area increased (10.8%) during the first period but declined (-7.9%) in the latest period resulting in a small basal area increase (2.1%) over the full monitoring period. This analysis has implications for the start and end dates for any future carbon monitoring scheme in grazed woodlands. A common observation across the regions and vegetation types analysed was the generally consistent increase in 'other woody species', indicating the woodlands are becoming more 'shrubby'. Another factor highlighted in these analyses is the large variation between individual sites in woody vegetation change. This variation will hinder accurate prediction of change at any individual woodland site.

A large part of the success of the project is due to the 91 landholders around Queensland who have trusted and collaborated with the project by providing access to individual TRAPS woodland monitoring sites on their properties. Their generosity has enabled the TRAPS woodland monitoring network to accurately measure change in the woodlands, providing a base dataset to assess the phenomenon of woodland thickening and its implications for carbon storage, and through modelling, the impact on grass production and profitability for the beef industry. A book is in production which outlines the changes occurring in the woodlands, describes a simple woodland monitoring technique and discusses some external factors driving policies which affect Queensland's woodlands.

Executive Summary

On-ground monitoring of woodlands provides a baseline for discerning the general trend of woody vegetation change across the landscape and over time. As woody species compete with pasture for water and nutrients, any directional change in tree-grass balance has implications for the sustainability and productivity of the cattle enterprise. The grazed woodlands of Queensland are a significant pastoral resource covering approximately 60 M ha and supporting approximately 2.1 M cattle. The project objectives were to consolidate an on-going system for quantifying and understanding trends in woodland structure and composition across Queensland's grazed woodlands; to produce tools and models to enable extrapolation and prediction of trends across the grazed woodlands; and to enable land managers to detect trends in woodlands and respond accordingly.

Our project has improved the value of the TRAPS woodland monitoring network, particularly through much more effective data storage and manipulation. This has facilitated (1) updating of trend analysis for the central Queensland sites for which there are now 20 years of data, (2) identifying variation in woodland trends due to climate and vegetation type, (3) linking with remotely-sensed methods of monitoring that offer broader spatial application and (4) linking with a modelling tool to help distinguish climatic and management influences on woodland change.

We now have data for TRAPS sites in central Queensland since 1985. For ironbark woodland sites, previous analysis has shown that, up until 1999, basal area increased by 10.8% overall. However from 1999-2005 those same sites have seen a decline in basal area of 7.9%, giving a net increase in basal area over the 20 years of only 2.1%. In contrast, box woodland sites increased in basal area by 19% from 1985 to 1999 and have had little change from 1999-2005, giving a net increase of 20% for the 20-year period. The variations in growth over different time periods, and for different woodland communities, has implications for both grazing land management and for the 'rules' under-pinning any future carbon accounting scheme in savanna woodlands.

A greater geographical distribution of sites have been monitored since the late 1990's. From 1999-2005, a relatively dry period, the data suggest significant regional differences in woody vegetation response. The analysis split sites between three regions, south, central and north, and also between two vegetation types, remnant ironbark and remnant box. For ironbark sites, the basal area of eucalypts declined by 7.3% and 1.3% in Central (n=17) and North (n=14) regions, respectively, while it increased in the Burnett (n=5) region by 5.1%. In contrast, the basal area of the 'other woody species' increased greatly in the Burnett region (89%) and modestly in the Central region (14.3%). The population of 'other woody species' increased across all regions by 10 to 43%. At the regional scale the predominantly dry conditions of 1999-2005 appear to have had the greatest impact on eucalypts in Central Queensland ironbark woodlands with a population decline of 9%.

Similar analysis of remnant box sites showed that the basal area and population of eucalypts for sites in Central (n=10) and North (n=8) regions are relatively stable. However, the 'other woody species' have increased substantially, with their basal area increasing by 24% and 60% in the central and north regions respectively.

A common observation across all regions and vegetation types analysed was the consistent increase in ‘other woody species’ (non-eucalypt species). Many of the ‘other woody species’ are shrubby mid-storey species indicating that, while trends in the upper-storey can vary, the woodlands are generally becoming more ‘shrubby’ in structure and composition, with major implications for visibility, mustering ease and pastoral production.

While the analyses have revealed general trends at the regional scale, there is a highly variable response between individual sites. This variability means that accurately predicting change at an individual site or over relatively small areas will be difficult, and this will make reliable monitoring of carbon stocks in woodlands somewhat problematic.

In addition to analysis of site data, three collaborative activities helped develop and improve tools to extrapolate estimates of woodland change across the landscape and to improve models that can predict the response of woodlands to climate, fire and grazing. The first collaboration compared estimates of woodland change from Qld EPA’s aerial photography technique with estimates from TRAPS data at common sites. Although the aerial photo technique and TRAPS technique were able to generate similar values for site basal area, the basal area change estimates were significantly different at common sites, being 0.075 $m^2.ha^{-1}.yr^{-1}$ and -0.013 $m^2.ha^{-1}.yr^{-1}$ for the TRAPS and aerial photo techniques respectively. This exercise highlighted the strengths, weaknesses and caution needed in interpreting change at regional and local scales using either technique and supports the notion that a range of techniques are required to compliment each other and discern ‘real’ change across different spatial and temporal scales.

The second collaboration compared woodland change from TRAPS monitoring sites with satellite-derived estimates of change in projected foliage cover using Natural Resources and Water’s SLATS data. The satellite-derived estimates showed potential to become an important tool for monitoring tree cover change across the landscape, with data from many sites closely aligning with change measured at the ground-based sites. At some sites, however, the two techniques did not agree on the direction of the trend and the reasons for this needs further exploration. This exercise again highlighted the need for a range of techniques, providing multiple sources of evidence, to reliably identify spatial and temporal trends . The third collaboration, through the Tropical Savannas CRC, used the CSIRO FLAMES model of fire and vegetation to help separate the impacts of climate and fire in driving vegetation change. This analysis showed that high fire frequency will likely maintain a low and relatively stable tree population, while low fire frequency results in a higher tree basal area which is also quite variable. When high tree basal area coincides with a major drought, the tree population crashes. The follow-on implications for landscape function, biodiversity and enterprise productivity of these crashes requires further investigation. As part of on-going modelling, the likely benefits and costs of using fire to reduce woodland density and increase grass production is being explored.

The project owes much to the 91 landholders around Queensland who have provided access to individual TRAPS woodland monitoring sites on their properties. These landholders have been kept up-to-date about changes that have occurred at monitoring sites on their properties through a co-operator feedback package and an annual letter.

The project has successfully built on the foundations provided by the TRAPS network and revealed that, while most woodland sites continue to show a thickening trend, there is large temporal and spatial variation. On-going modelling and broad-scale monitoring, combined with reliable ground-based data such as that from TRAPS, will help understand the drivers of this variation as well as identify management options for research and/or demonstration.

Contents

1 Background

1.1 Background

A network of 111 woodland monitoring sites have been progressively established in the grazed woodlands of Queensland since the early 1980's. These monitoring sites have been useful for providing data on woodland change and the implications for carbon sequestration and pasture production. Knowledge of woodland change can be used to help motivate management interventions the benefit on-going profitability, landscape function (including hydrology and biodiversity) and sustainability. The grazed woodlands are a major pastoral resource in Queensland covering approximately a third of Queensland (~60 Mha) and supporting approximately 2.1 M cattle.

Rigorous monitoring methods, field data capture programs and the 'winTRAPS' program for analysis of individual sites had been established as part of the monitoring network.

The aim of this project was to build on the significant resource of the TRAPS network of monitoring sites by improving the network of sites, improving data handling and processing, and generating products suitable for a range of end users (eg. land managers, scientists, modellers, policy makers).

2 Project Objectives

1. Establish a verifiable, comprehensive and on-going system for quantifying and understanding change (trends) in woodland structure and composition across the pastoral woodland communities of Queensland.

2. Produce tools and models to extrapolate and predict patterns of woodland change in the pastoral woodland communities.

3. Produce tools and practices for beef producers to monitor and manage woodland change.

3 Methodology, results and discussion

The activities undertaken in the project can be grouped into three broad areas which generally fit under the three objectives. Because of the large number of activities undertaken by the project, the methodology, results and discussion are combined for each activity. The three broad areas into which the activities have been grouped are:

1. Updating and improving the monitoring network
2. Using the data
3. Communication.

3.1 Updating and improving the monitoring network

Major activities undertaken in this section are:

- Developing the DYRAD database and demonstrating the use of data extracted from the database.
- Identifying gaps in the monitoring network and proposing new sites.

- Field site sampling.
- Establishing a photo pairs database.

3.1.1 DRYAD database

The objective of the DRYAD database development was to ensure efficient and reliable storage of the TRAPS monitoring data (Figure 1). A process has been developed to enable efficient data entry, data storage and data extraction. The database can now efficiently produce output on tree basal area, species population and shrub basal area for each site at each recording date. Climate data has also been integrated into the database for each site. Known management information and future management information (obtained from landholder feedback) can be incorporated into the database.

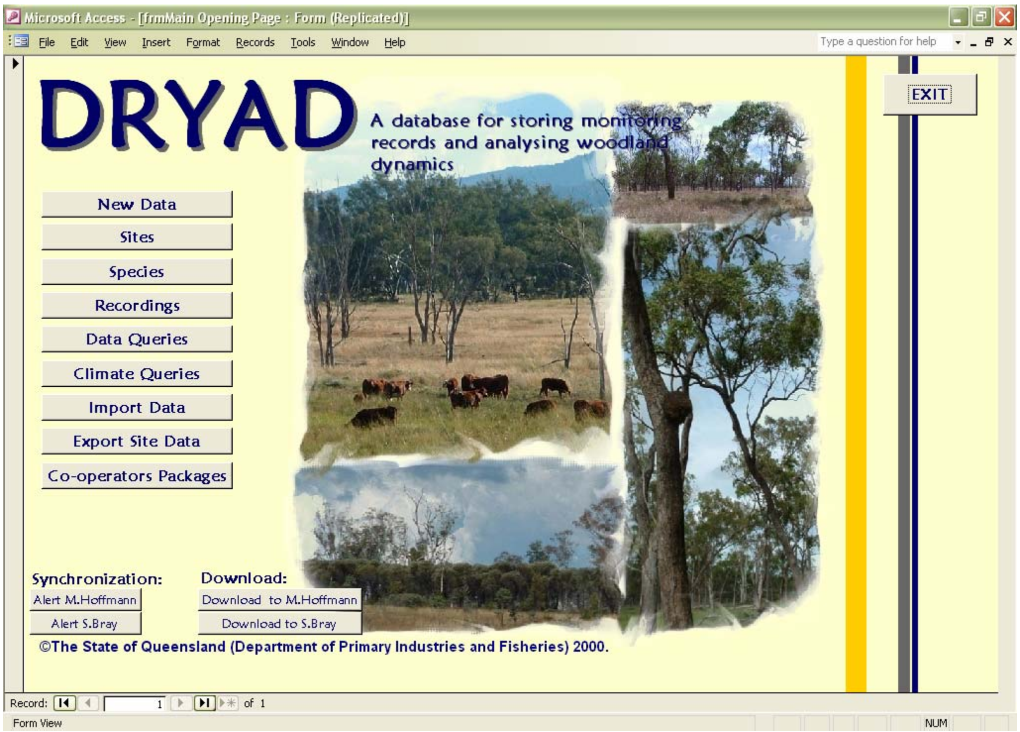

Figure 1 Front page of the DRYAD Woodland Dynamics Database

The ‘Site information’ page (Figure 2) enables site information and site recording history to be extracted. For example, latitude and longitude of each site, a list of woody plant species at a site, initial and last sampling date and number of site recordings. A list of sites where a particular species occurs can also be generated.

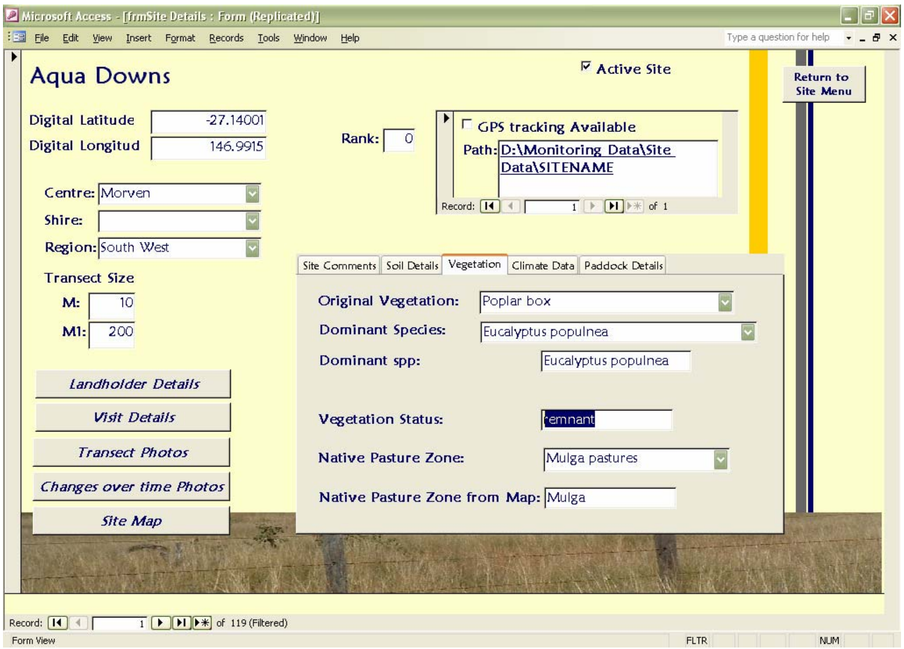

Figure 2 DRYAD database site information and site recording history page.

A process has been developed to efficiently import new site recording data into the database (Figure 3). To improve field recording efficiency the TRAPS data capture program stores previous data in the same file as the recent data. Therefore when updating the database care needs to be taken to only add the new data and not enter duplicate data for previous recording dates. A three stage process has been developed to ensure reliable importing of new site data into the database.

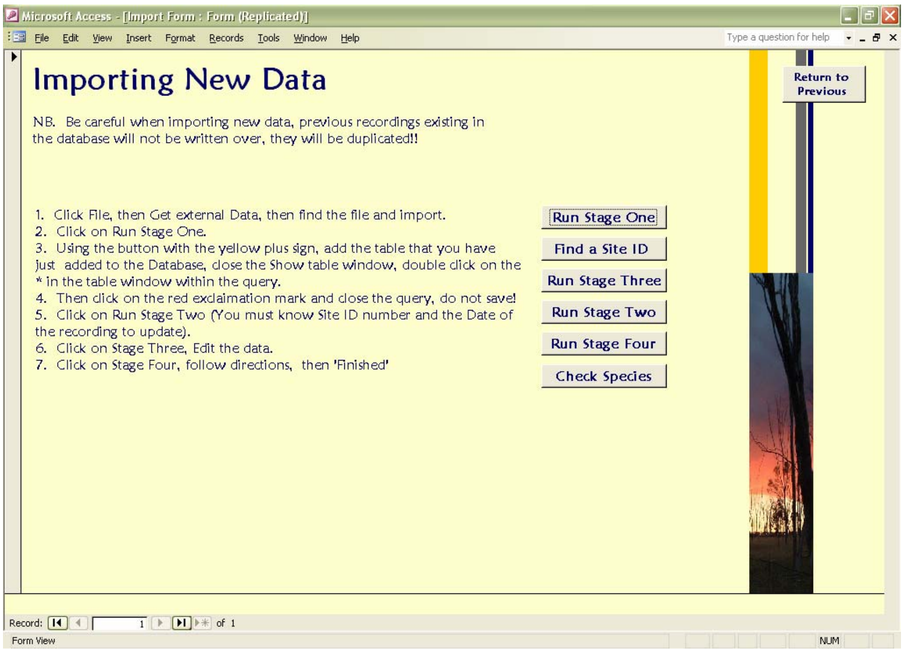

Figure 3 DRYAD database page for importing a recent site recording.

Data summaries can be simply extracted from the 'Data Queries' page (Figure 4). Key data summaries include:

- Total live basal area at each site at each recording date
- Basal area change between recording dates
- Plant population (count) at each recording date.

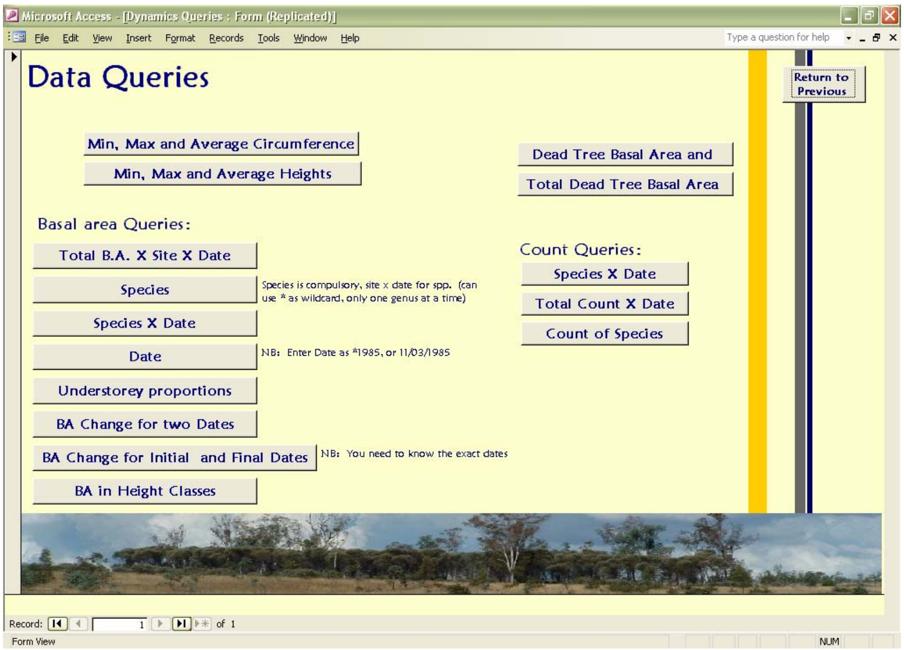

Figure 4 DRYAD database page for extracting data summaries from the database.

The database can also output data summaries (Figure 5) that are used to generate tables and graphs in the 'Co-operator packages'. Co-operator packages have been designed as a project extension tool to help develop and maintain relationships and provide feedback to co-operators (see Section 3.3.1 and Appendix 9.2).

Currently, the database queries generally report on an all-site or a per-site basis. Grouping of sites to assess vegetation type, remnant status, or regional trends still needs to be conducted with care to ensure the sites are suitable for grouping. The sites are dynamic and subject to landholder management and have different prior histories, therefore it would not be sensible to group all narrow-leaf ironbark sites (remnant and cleared) to assess basal area change through a drought time period. The database is designed to compile and summarise the data. It is not a complete data analysis tool, but will provide output for data manipulation and analysis in other statistical packages.

Prior to the development of the database, analysis data could be generated for individual sites from the winTRAPS program with individual results from each site and each sampling date being individually transcribed onto a datasheet which took considerable time. The database can now generate the data for all sites quickly and efficiently. However, care is still required to remove sites, dates etc that are not appropriate or required for specific analyses.

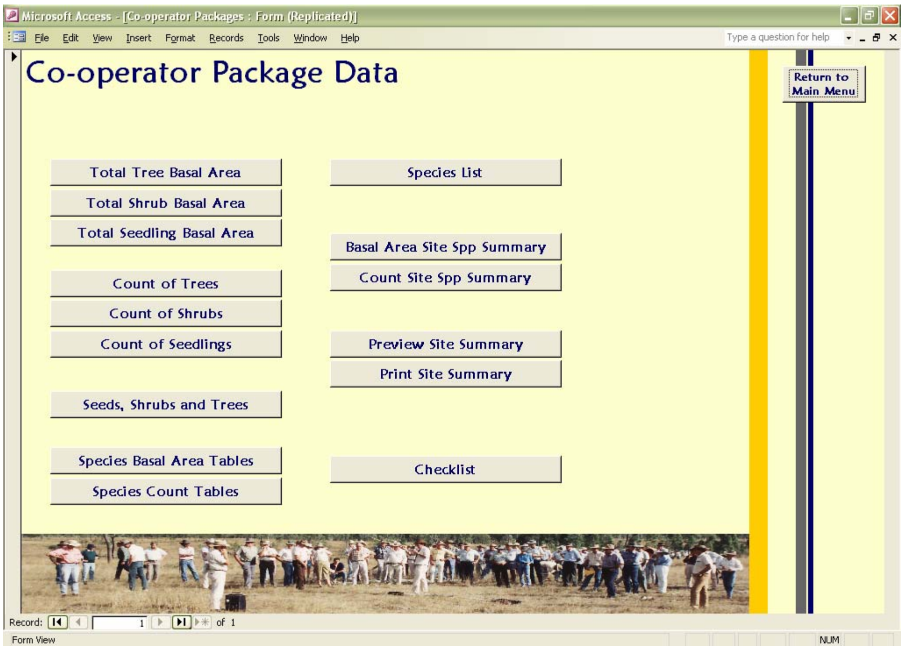

Figure 5 DRYAD database page to extract individual site data summaries for the 'Co-operator packages'.

To present recently acquired data and to demonstrate what can be done with data extracted from the database we have asked the following three key questions as examples:

1. Is there a **regional difference** in vegetation response in the **1999-2005 period**?
2. Is there a **vegetation type** response in the **1999-2005 period** and over the previous **1985-1999 period**?
3. What has been the **response of** some specific **understorey species** like red ash (*Alphintonia excelsa*) and quinine (*Petalostigma pubescens*)?

Is there a regional difference in vegetation response in the 1999-2005 period?

Prior to this project most TRAPS sites were last recorded in the period 1998-2000. Since that time most of the woodlands in Queensland have experienced a number of years of significant drought. The latest sampling, 2003-2006, recorded the impact of the drought, but are there regional differences?

Live tree basal area and woody plant population data were extracted for remnant ironbark and box sites sampled in the 1998-2000 period and the 2003-2006 period. The sites were divided into three regions; Central, North and Burnett (South). Central region covers the Fitzroy basin and Central West, the Burnett region included predominately the Burnett catchment and North region was classified as north of a line between Mackay and Belyando Crossing. The woody vegetation was also split into 'Eucalypts' (includes *Corymbia* species) and 'Other woody species'. The change in live tree basal area and tree population was averaged across sites.

Figure 6 shows regional and species differences during the last monitoring period (average 1999 to 2005). For the remnant ironbark sites, the basal area of eucalypts declined by 7.3% and 1.3% in Central (n=17) and North (n=14) regions respectively while increasing in the Burnett (n=5) region by 5.1%. In contrast, the basal area of the 'other woody species' increased greatly in the Burnett region (89%) and modestly in the Central region (14.3%). The 'other woody species' population increased across all regions by 9.8 to 43%, while the Eucalypt population declined in the Central region.

The pattern for Eucalypt basal area and population for the remnant box sites in Central (n=10) and North (n=8) regions indicates they are relatively stable. However, the 'other woody species' have increased substantially, with basal area of 'other woody species' increasing by 24% and 60% in the central and north regions. Many of the 'other woody species' are shrubby mid storey species indicating that the box remnant woodlands are becoming more 'shrubby' rather than 'open' which potentially affects visibility, mustering ease and pastoral production.

At the regional scale the drought in the 1999-2005 period appears to have had the greatest impact on Eucalypts in remnant ironbark woodlands in Central Queensland with a decline of 9% in tree population. However, even during the drought period, the population of 'other woody species' appears to be generally increasing across the woodlands (9-57%).

Although this analysis has indicated general trends at the regional scale, the error bars (Figure 6) indicate a highly variable response between individual sites. This variability means that accurately predicting change at an individual site or over relatively small areas will be difficult and will impact on methods used in any future carbon trading scheme in woodland vegetation.

Is there a vegetation type response in the 1999-2006 period and over the previous 1985-1999 period?

In this exercise we tested the impact of the latest dry period (1999-2006) against the previous period (1985-1999) and total period (1985-2006) for the long term remnant TRAPS sites in central Queensland (Figure 7; Figure 8).

In ironbark woodlands, the basal area increased during the first period as reported in (Burrows *et al.* 2002). However, during the latest period, the basal area has declined resulting in only a small basal area increase across the full period. The basal area of other woody species has continued to increase.

In box woodlands, there was little change in eucalypt basal area during the last period after an increase in the first period.

The implications of these results is that basal area change rate predicted by (Burrows *et al.* 2002) would now be lower if the analysis was extended over the full period.

What has been the response of some specific understorey species like red ash (*Alphintonia excelsa*) and quinine (*Petalostigma pubescens*)?

As indicated in the previous two analyses, the 'other woody species' category appear to be generally increasing across regions and across the ironbark and box broad vegetation types.

This simple analysis looks at two common ‘other woody species’ *Alphitonia excelsa* (red ash) and *Petalostigma pubescens* (Quinine) (Figure 9). The long term, central Queensland sites were used in this analysis.

Alphitonia excelsa increased at four of the six sites where this species occurred in reasonable quantities (>0.05 m^2/ha at some stage during the monitoring period). The two sites where basal area of this species declined indicate the basal area was initially high and further increased to the early 1990’s whereafter it subsequently declined. By cross checking with the winTRAPS program this decline was due to the death of some large trees.

Petalostigma pubescens increased at five of the six sites, with substantial increases at some sites (eg. Tryphinnia E. crebra, Kaiuroo and Tryphinnia E. molucanna). **Error! Reference source not found.** provides graphic photographic evidence supporting the change measured by the TRAPS recordings at one site.

These analyses demonstrate the potential application of data extracted from the DRYAD database. Without the development of this database, data extraction and analysis in other programs was extremely difficult due to the massive number of records (approximately 250,000, MS Excel is limited to a maximum of 65,000 rows).

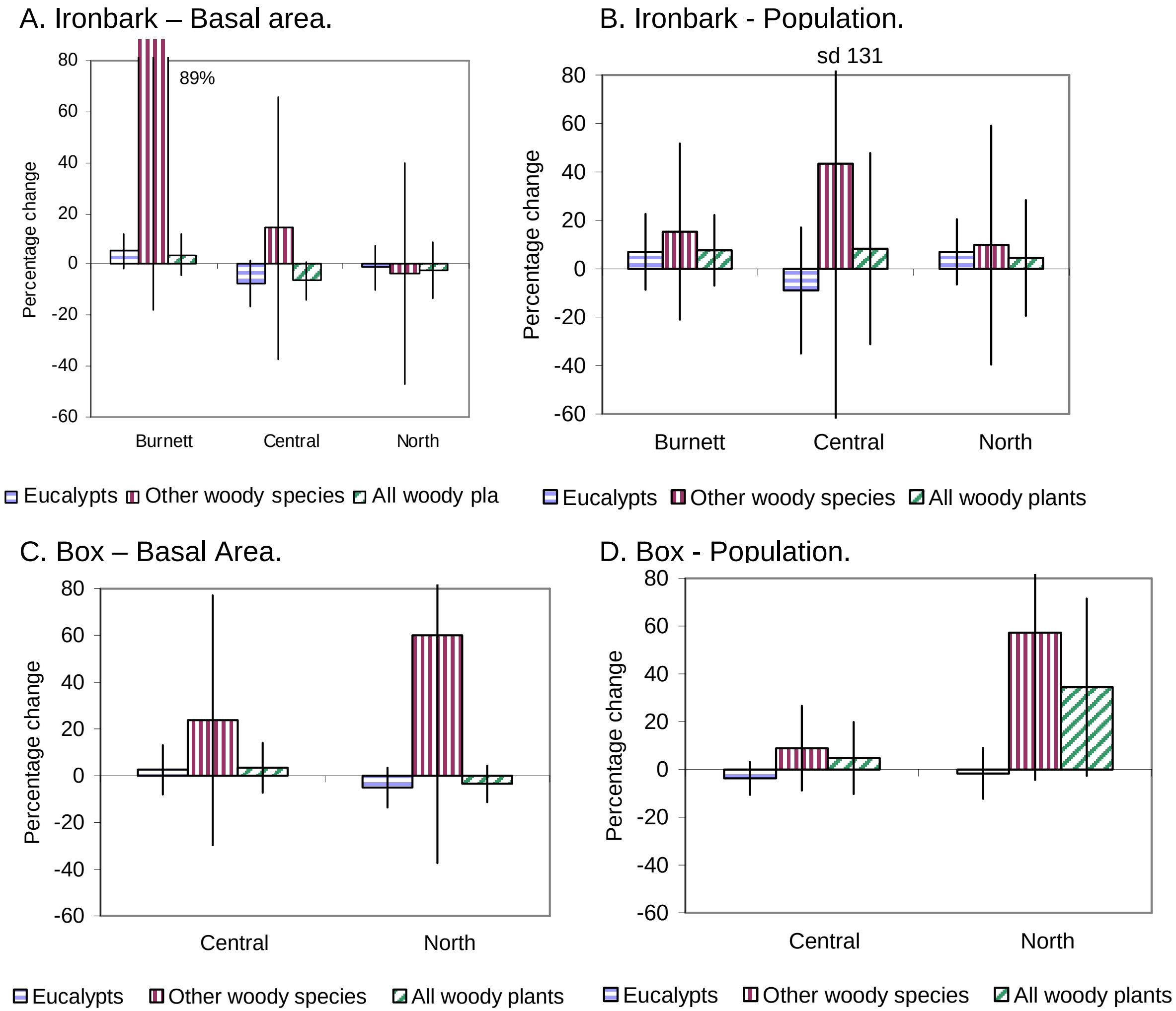

Figure 6 Percentage change between an average date of 1999 and an average date of 2005 for basal area and plant populations for eucalypts, other woody plant species and all woody plants in remnant ironbark sites in southern, central and north Queensland regions and remnant box tree sites in the central and north regions. Error bars (sd) represent the variation in individual site response.

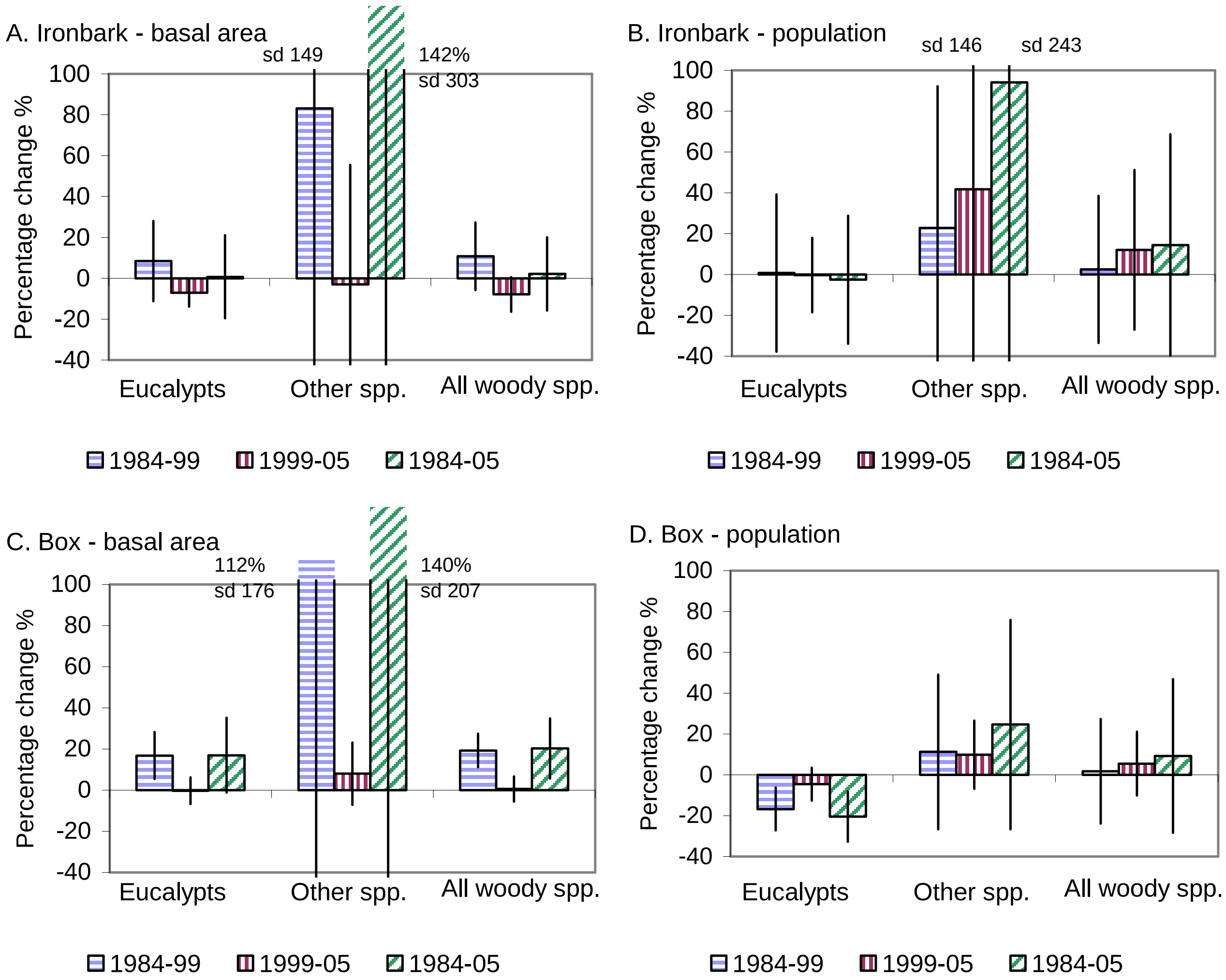

Figure 7 Percentage change in basal area and plant population for eucalypts, other woody plant species and all woody plants at the long term ironbark 'TRAPS' sites in central Queensland between three periods (1985 - 1999; 1999 - 2005; 1984 - 2005). Error bars (sd) represent the variation in individual site response.

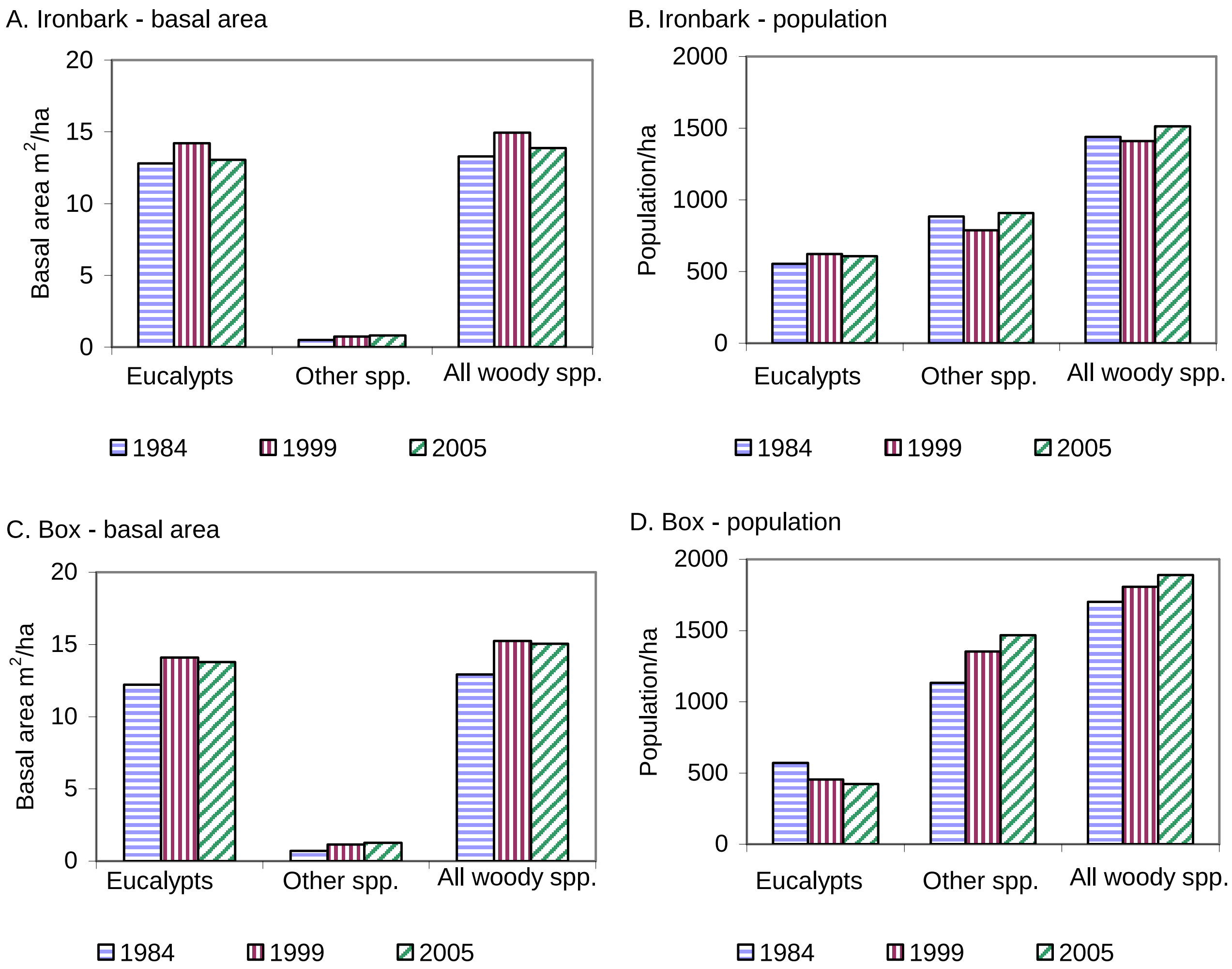

Figure 8 Mean stand basal area (at 0.3m) and population for eucalypts, other woody plant species and all woody plants at the long term 'TRAPS' sites in central Queensland at average recording dates of 1984, 1999 and 2005.

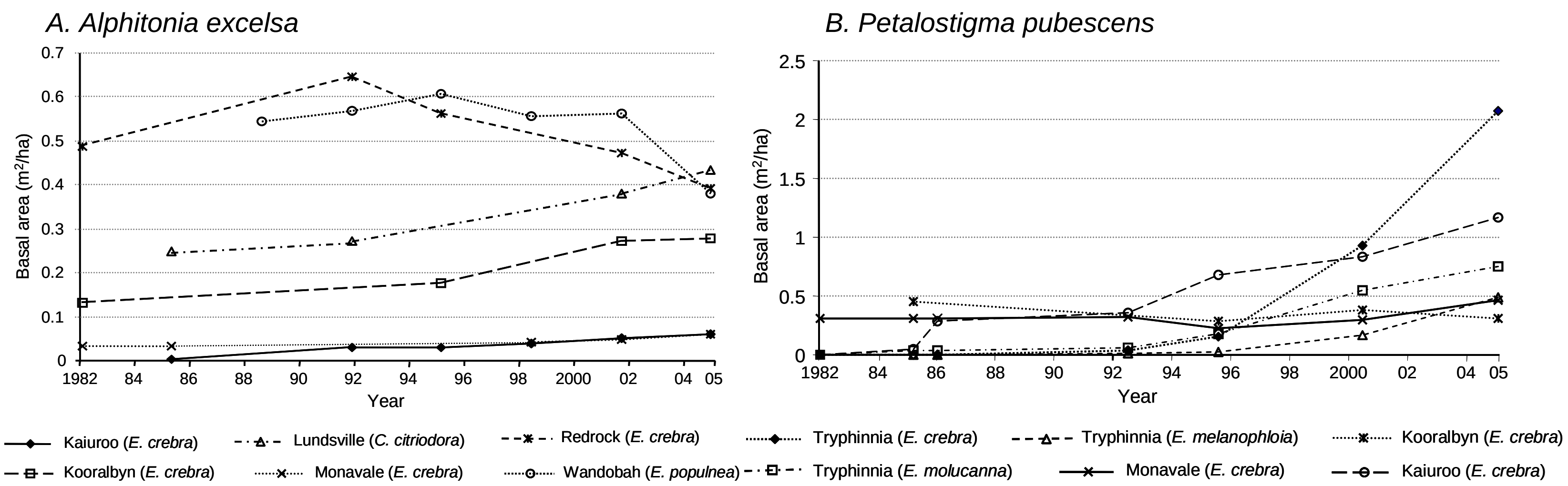

Figure 9 Change in basal area (at 0.3m) of two major understorey woody species at individual sites A. *Alphitonia excelsa* and B. *Petalostigma pubescens*.

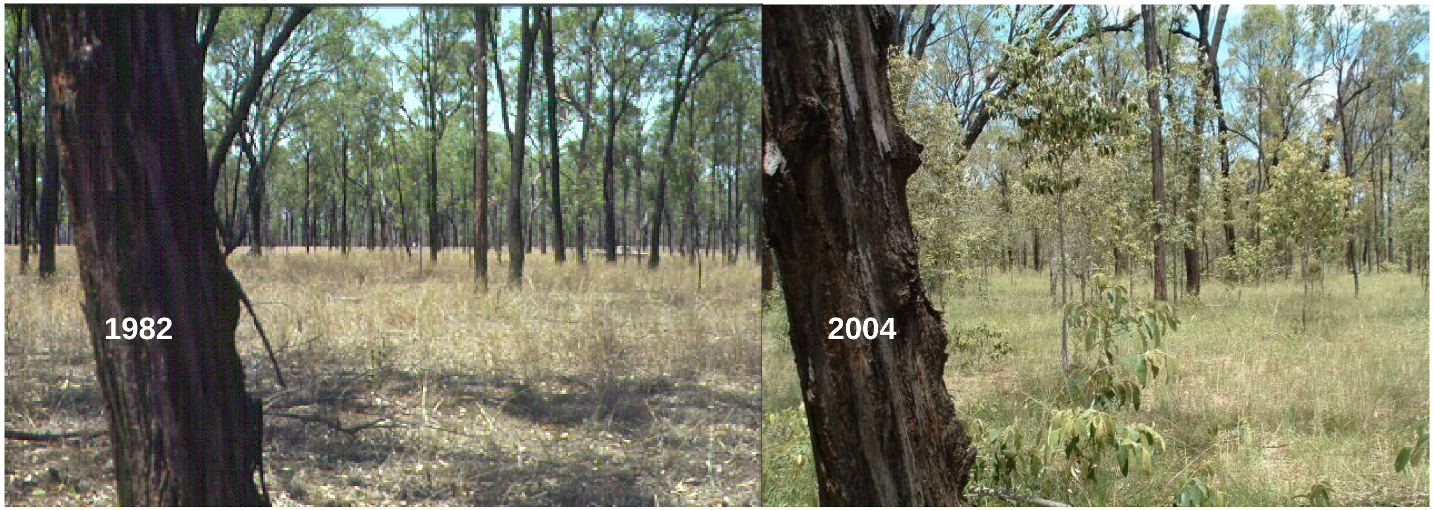

Figure 10 Photographic evidence of the change in the shrubby understorey at a long term TRAPS site in central Queensland. The photo on the left was taken in 1982 and the photo on the right in 2004.

3.1.2 Identifying gaps in the monitoring site network and proposed location of new sites

The aim of this activity was to:

- Determine the region represented by the current TRAPS sites.
- Locate gaps in the area represented.
- Identify new sites to fill the gaps and improve representativeness of the monitoring network assuming two levels of improved resources.

A GIS (geographic information system) analysis process was carried out to test the representativeness of the existing TRAPS network against the remnant woodland in a defined study area of Queensland (Figure 11)(analysis detail is presented in Appendix 1). A total of 108 TRAPS sites, including 18 non-remnant (cleared) vegetation sites were used in the analysis. The proportion of sites representing classes within the attributes; broad vegetation group (BVG) (based on EPA regional ecosystem mapping), soil type, tree basal area (BA), and wettest quarter rainfall and temperature were compared to the proportion of the area in the study region. The results were used to determine any gaps in the monitoring network and where new sites should be located for maximum benefit in correcting deficiencies.

In summary, the current TRAPS sites were representative of the overall study area for basal area, rainfall and temperature. However, the current TRAPS sites were not representative for broad vegetation group or soil type (see below). This difference is largely due to historical factors which impacted where sites were initially established. The early TRAPS sites were mostly established in the Central Queensland region in grazed woodland vegetation (predominately ironbark and box). This has meant that at a larger regional scale these vegetation types are over-represented (based on site number) relative to other vegetation types outside central Queensland (which have a 'low' site number relative to the area of that vegetation type). To correct this deficiency in the existing site distribution, two networks of new sites were developed. One network (high priority sites) corrects the most deficient attribute classes with 17 new sites (establishment of 17 new sites was seen as possible with slightly improved resources)(Figure 12). The second network (grid sites) fills remaining spatial gaps left by the original TRAPS sites and the 17 new sites (55 sites)(Figure 13). It represents an improved woodland monitoring network given significant additional resources.

High priority site selection

Under-represented attributes (eg. Broad vegetation group 24 – mulga on red earth plains, sandplains and residuals) were identified and used as the basis to select areas in which to install new sites. To maximise correction of representativeness, selected classes for the attributes broad vegetation group, soil type, rainfall and temperature were overlaid to identify 'envelope' areas that would improve representativeness for more than one attribute. Envelopes were ranked based on area. Sites were randomly selected within selected envelopes provided they were greater than 20 km from another site and not located in obviously inaccessible areas (eg. military training areas). The location of 17 new sites was identified (Figure 12). The original sites plus the 17 new sites were representative of the study area for all attributes (Figure 14 a,b).

Establishment of 17 new sites was seen as possible given slightly improved resources. However spatial gaps still remained in the study area where no sites were located (Figure 12).

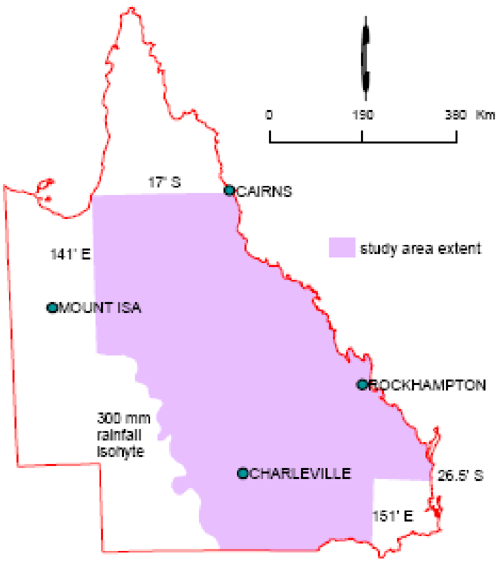

Figure 11 Map of the woodland study area targeted by the TRAPS woodland monitoring network.

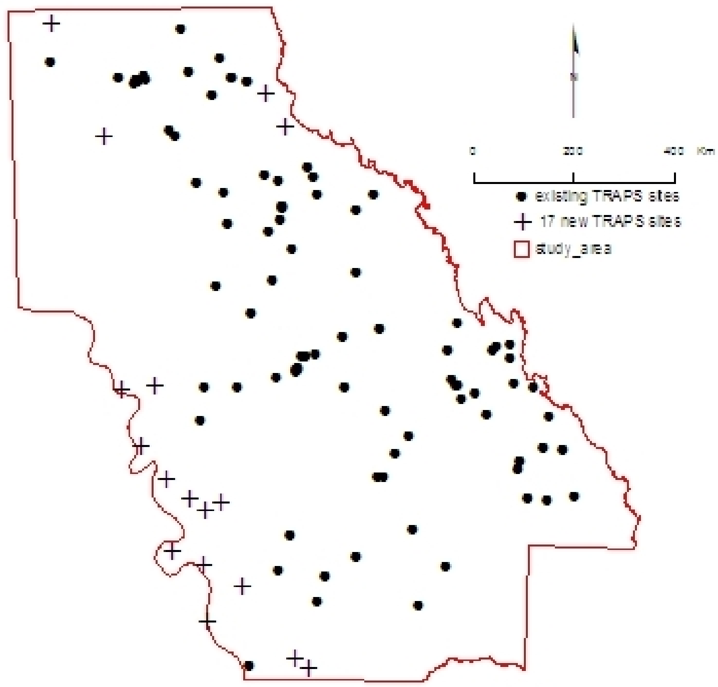

Figure 12 The study are showing the original TRAPS sites and the 17 new high priority sites.

Grid site selection

Although the 17 high priority sites identified above significantly improved representativeness of the study area, significant spatial gaps remained in the study area without sites. Therefore a second set of sites was developed to fill the spatial gaps and provide improved spatial coverage. Establishment of these sites was viewed as possible given significant additional resources.

A 50 km buffer was generated around the existing TRAPS sites and the 17 high priority sites. A 100 km grid was then placed over the study area to avoid bias in site location. 55 sites were identified outside the buffer areas. Each point was examined to ensure that it was located at least 500m from a non remnant vegetation area boundary and soil type could be determined from the soil layer. Points that did not satisfy these conditions or lay in a non-remnant area or ‘non-mask’ area were moved to the closest suitable position (Figure 13). The original sites plus the 17 new high priority sites plus the 55 new grid sites (total 162 remnant sites) were representative of the study area for all attributes (Figure 14 a,b).

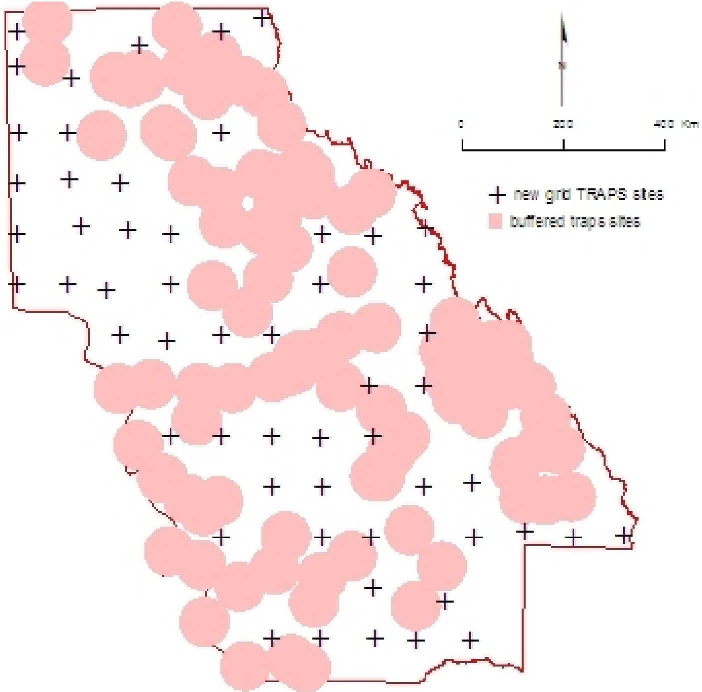

Figure 13 The original TRAPS sites and 17 proposed high priority sites with a 50km radius buffer (pink dots) and the 55 proposed grid sites.

For more details on this analysis see Appendix 1.

The addition of the new sites would greatly improve the representativeness of the TRAPS woodland monitoring network, but site establishment and follow-up monitoring represent a major investment in additional resources. Future resource needs are discussed in Section 4.2.

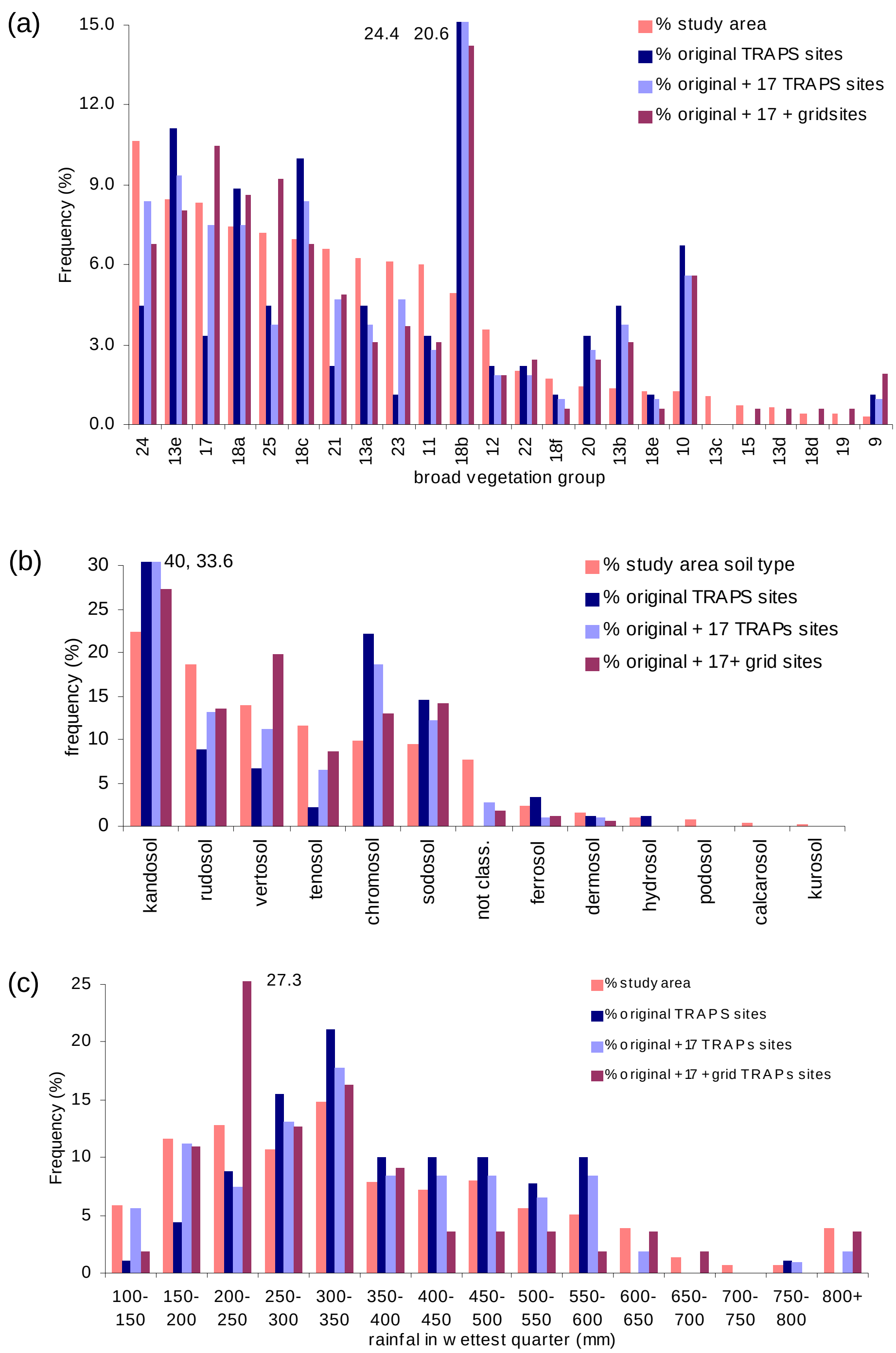

Figure 14a. The representativeness of the attributes broad vegetation group (a), soil type (b) and rainfall in the wettest quarter (c) of the original TRAPS, original +17 sites and original +17 +grid sites, against the proportion of the attributes in the study area.

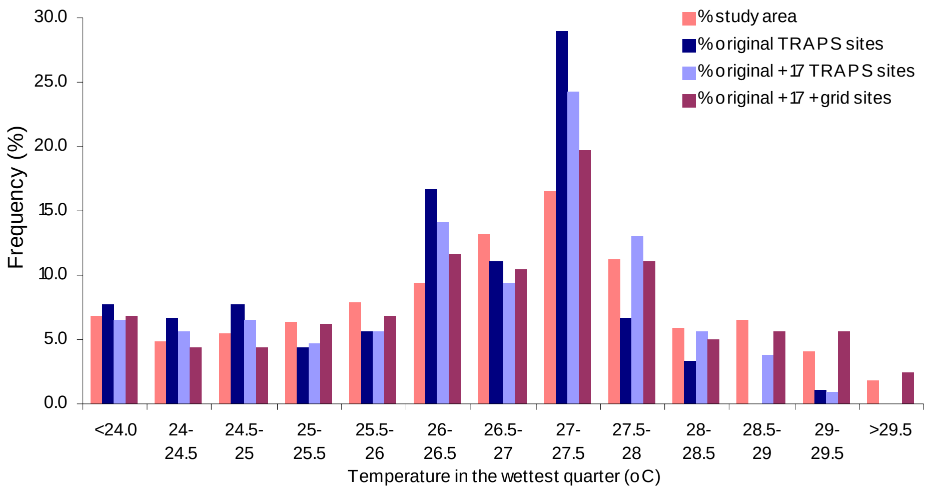

Figure 14b. The representativeness of the attributes ‘temperature in the wettest quarter’ of the original TRAPS, original +17 sites and original +17 +grid sites, against the proportion of the attributes in the study area.

3.1.3 Field site sampling

Field site sampling is the cornerstone of the TRAPS woodland monitoring network and provides the base data for the measurement of woody vegetation change. At the start of the project, existing TRAPS woodland monitoring sites were assigned a priority for re-sampling using a desktop exercise. This prioritisation exercise was based on the time since last recording and site integrity. Seventy-two sites (of 111) have since been re-recorded generally based on level of prioritisation and proximity to other sites. Two new sites (Gleumel3 and Raby Creek) were established as part of other projects (not part of the previous site selection exercise) but provide an opportunity to expand the monitoring network and field recordings have been incorporated into the database. In addition, site location mudmaps were checked and amended if necessary, and some mudmaps were created where they did not exist. Mudmaps are linked to the database but are stored with the field data collection files and transect photos. The site GPS location was also checked and amended if necessary to allow for accurate site re-location and to enable accurate positioning of sites on satellite imagery.

Table 1 lists the sites recorded during this project and provides an indication of change since the last recording.

Table 1 Sites recorded during project and change in basal area and plant population since the last recording (generally 1998-2000 period). See section 3.1 for data analyses at the vegetation type and regional scale.

Site Name	Date recorded	Basal area change %	Population change %	Comments
Hedlow Creek	17/02/2003	-3.4	-6.2	
Raby Creek	15/07/2003 31/05/2006	10.1	5.9	First and second recording
Langley Flats	12/08/2003	-94.5	-40.9	Site Tordoned
Old Rawbelle	13/08/2003	0.6	-6.9	
Scotston	13/08/2003	3.8	19.5	New *Eucalyptus crebra* plants
Magazine	11/09/2003	-2.9	23.9	
Cooper Downs (4m)	5/11/2003	-3.2	60.3	Many new *Eucalyptus melanophloia* seedlings
Balmoral	6/11/2003	-12.0	36.4	Many new *Eucalyptus fibrosa* seedlings
Glen Innes EUMEL3	9/12/2003			First recording
Glen Innes EUMEL1	11/12/2003	-2.5	-1.6	First recorded 2001
Kiauroo small trans	3/02/2004	-16.7	-2.7	4 big trees died
Duckworth	5/02/2004	-51.5	-1.0	Cleared site
Tryphinia View Eumel	18/02/2004	-6.2	1.4	
Tryphinia View Eucre	19/02/2004	-4.8	8.1	
Tryphinia View Eumol	1/03/2004	-0.5	31.1	Increase across most spp.
Kooralbyn Eucre	2/03/2004	-2.2	14.8	
Hyde Park	15/03/2004	-1.9	13.6	Increase in small shrubs
Summerdell Pulled	16/03/2004	-85.5	-18.5	Pulled 2003
Summerdell Control	17/03/2004	-91.4	-22.6	Pulled 2003
Texas	18/03/2004	-99.8	-53.1	Pulled 2001, very hot fire 2003
Mona Vale	18/05/2004	-10.7	4.4	
Rundle	19/05/2004	-6.5	-7.9	
Bagstowe	4/06/2004	7.6	29.3	Increase prickly pine and cypress pine seedlings
Mayvale	5/06/2004	15.2	1.5	Tea tree site
Forest Home	6/06/2004	1.3	12.0	
Rockdale	7/06/2004	-4.0	3.8	
Namuel	7/06/2004	-2.9	21.1	
Mt. Turner	7/06/2004	-3.3	6.2	
Mistletoe	8/06/2004	0.1	0.6	
Lanes Creek	8/06/2004	3.8	35.7	
Rocky Springs	8/06/2004	0.2	43.4	more shrubs
Bolwarra	9/06/2004	5.7	28.3	*Eucalyptus cullenii* seedlings

Site Name	Date recorded	Basal area change %	Population change %	Comments
Gilldale	10/06/2004	7.2	40.7	more shrubs
Mt. Pleasant	12/07/2004	-10.7	3.3	*Eucalyptus melanophloia*
Nyanda	13/07/2004	-4.1	103.2	Increase in *Acacia leiocalyx*
Canal Creek Mature	28/07/2004	-6.7	22.4	*Melaleuca viridiflora*
Werrington	10/08/2004	-21.6	115.7	Increase *Acacia victorii* & old death
Mount Emu Plains	11/08/2004	-4.2	16.7	*Eucalyptus brownii*
Julia Park	12/08/2004	0.1	7.9	*Eucalyptus similis*
Goldsborough	31/08/2004	-4.0	-9.8	*Eucalyptus quadricostata*
Myrrlumbing	31/08/2004	1.5	43.5	Increase in *Carissa lanceolata*
Longton	2/09/2004	-15.7	-3.5	*Eucalyptus melanophloia*
Glen Innes (Eupop 1)	27/09/2004	1.3	-3.6	*Eucalyptus populnea*
Glen Innes (Eumel 2)	19/10/2004	0.6	-1.2	*Eucalyptus melanophloia*
Glen Innes (Eupop 2)	21/10/2004	-1.4	-8.6	*Eucalyptus populnea*
Rosebank	11/04/2005	-4.9	12.9	*Eucalyptus crebra*
Dykehead	12/04/2005	17.2	13.6	*Eucalyptus melanophloia*
Wandobah Control 1	18/04/2005	3.4	-5.4	Death *Grevillea striata*
Wandobah Control 2	24/05/2005	-2.4	0.6	
Wandobah Control 3	30/05/2005	-1.5	3.5	
Coalston Lakes	4/10/2005	-6.6	-39.6	Severe fire, trees burnt off
Burtle	25/10/2005	-52.2	-36.8	*Eucalyptus melanophloia* dead
Glenrock	22/11/2005	-4.8	2.5	Droughted
Wairuna	8/12/2005	-5.4	-5.1	
Princess Hills	9/12/2005	8.5	-7.6	Burnt between recordings
Sugarbag South	11/12/2005	5.9	-20.3	Burnt between recordings
Leyshon View Grazed	13/12/2005	24.5	47.6	*Acacia farnesiana* increase
St. Paul's Exclosure	13/12/2005	-8.0	-36.2	
St. Paul's Grazed	13/12/2005	-31.5	-12.9	
Medway	6/02/2006	0.3	-13.8	
Hobartville	12/02/2006	0.9	-3.7	
Mt Pleasant Bowen	5/03/2006	-16.6	-9.2	Some drought deaths
Salisbury Plains	6/03/2006	402.8	-7.1	Regrowth site
Exevale	9/03/2006	-40.8	31.3	Droughted, Very low numbers
Heidelberg	9/03/2006	3.7	-22.4	
Tarabah	17/03/2006	30.2	22.0	Dead finish and myrtle

Site Name	Date recorded	Basal area change %	Population change %	Comments
				increase
The Patrick	20/03/2006	22.4	27.1	Regrowth site
Granite Vale	10/05/2006	-11.2	-14.7	*Eucalyptus crebra* deaths
Netherleigh	16/05/2006	-5.9	4.6	
Raby Creek	31/05/2006	6.3	-50.3	Many *Eucalyptus citriodora* seedlings dead
New Forest Hills	1/06/2006	35.6	-17.9	Burnt between recordings
Redrock	29/06/2006	-1.3	-22.8	Small plants dead
Lundsville Control	27/07/2006	2.0	-7.6	
Lundsville Tordon	15/08/2006	-11.2	-22.4	Small *Eucalyptus crebra* & *E. citriodora* tordoned

Two sites have been lost (Anchor – now a laneway and pegs removed; Springsure reserve – pegs gone, site disturbed). Ninety-one remnant sites are currently active in the database and 20 non-remnant sites are currently active in the database.

3.1.4 Photo pairs database

Photo pairs are a powerful visual tool for depicting historical vegetation change (eg. see Figure 15). In the past, collection of photo pairs has been haphazard. This has meant that there was no cataloguing of photo pairs, little record of who supplied the historical photo, little or no information on who owns the copyright to the photos, little information on accurate location of the photo, little record of past management which may impact on any change depicted in the photo pair.

To improve the recording and cataloguing of photo pairs, a photo pairs database was developed. This database has undergone testing and a basic instruction manual has been written. 'Field' forms were developed to collect data on a perspective photo pair for later input in the database.

Two legal forms were developed to clarify copyright issues:

- Photographic/image release form
- Deed of copyright licence

The search for photo pairs was advertised in a number of rural newsletters and the responses were followed-up. In addition, other contacts, often through family connections were followed up.

Fifteen photo pairs are currently in the database. The photo pairs depicted in Figure 16 to Figure 19 are an example of some of the photo pairs collected during this project.

Figure 15 Photo pair from ‘Wongalee’ in the mulga region SW Queensland.

Figure 16 The area in the original image was used by residents of Monal as a sports/picnic ground. Monal was a gold mining settlement near Monto in the Burnett/Central Queensland region. Operations at the mine ceased approx. 1908. The red arrowed trees are the same in each photo. The pink arrow shows tree growth on the hillside and the creek appears to contain more woody vegetation.

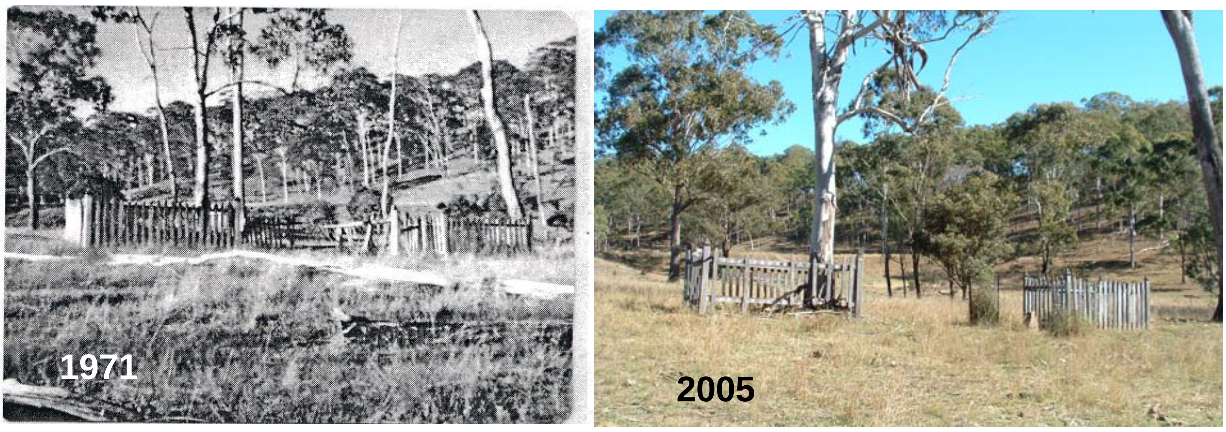

Figure 17 Monal cemetary. Monal was a gold mining settlement near Monto in CQ. Operations ceased approx. 1908. While some trees have been removed, the one inside the fence remains. The vegetation on the ridge in the background also shows signs of woodland thickening.

Figure 18 Alice River, Barcaldine, central Queensland. The image is looking along the river from the former vehicular crossing over the Alice River on the Barcaldine – Blackall road. The arrowed trees are the same in both images. Vegetation along the banks has increased in the intervening years.

Figure 19 Pine Rivers south east Queensland. The region was traditionally used for dairying where timber regrowth was regularly removed. The image on the left is a photo of the 1942 flood. Vegetation appearing along the creek in the foreground and on the far ridge in the 2005 image was not present in the earlier image.

3.2 Using the data

Major activities undertaken in this section include:

- Simulation modelling
- Aerial photography technique comparison
- Satellite imagery technique comparison
- Other activities

3.2.1 Simulation modelling

Simulation modelling provides a mechanism to extend measured plot data over longer timeframes, large regions and under different management. Formal links were developed with Garry Cook, Adam

Liedloff (CSIRO Darwin), Bill Holmes, Marnie McCullough and Chris Chilcott (DPI&F, Qld) through the CRC for Tropical Savannas, Dynamic Savanna project which bought together tree dynamics data, the FLAMES fire and landscape model, economic expertise, GRASP model output and grazing land management principles. The objective of this modelling exercise was to use ecological and economic modelling to predict and communicate the potential effectiveness of management interventions aimed at modifying woody vegetation structure on grazing properties.

The FLAMES fire and vegetation model was used to integrate fire, initial woodland condition and climate scenarios to generate a range of possible outcomes for a woodland in central Queensland. The model was parameterised for infertile red tableland country dominated by narrow leafed ironbark (*Eucalyptus crebra*) woodland (the Redrock TRAPS site west of Clermont). Clermont historical climate data (1886 to 2003) was used in the model and represents a typical summer dominant, semi-arid rainfall pattern for the region. Initial tree populations were based on data collected from the Redrock woodland monitoring site.

Four scenarios are presented, with each scenario a mean of three iterations of the model. The scenarios are:

1. 100% initial tree population and 1 fire every 10 years
2. 100% initial tree population and 1 fire every 2 years
3. 33% initial tree population and 1 fire every 10 years
4. 33% initial tree population and 1 fire every 2 years

The 33% initial population was generated by selecting every third tree down the list. A low initial population was included as there is evidence from historical records, paleoecological techniques (pollen in sediment, soil carbon isotopic analysis) that the woodlands were more sparse and open 100-200 years ago. The model included sustainable grazing, removing a proportion of the grass fuel which is a modification of the original model, developed as part of this exercise. Fire only occurred if sufficient fuel was present in a ‘fire year’ with the fire occurring in October (late dry season).

The results of this modelling exercise indicate that, if we assume the tree population in the late 1800’s was similar to the present day (high) and fire frequency is low (1 fire every 10 years) the live tree basal area would follow a cycle of increasing basal area until high basal area coincided with a major drought event resulting in substantial reduction of tree basal area (Figure 20). Tree basal area in the low initial tree population and low fire frequency scenario increased until the 1930’s becoming similar to the high initial tree basal area and low fire frequency for the rest of the simulation. These scenarios suggest there has been a general trend of increasing tree basal area since the 1960’s drought, followed by a recent decline in the early 2000’s drought.

If we assume the initial woodland population in the late 1800’s was one third the current population with high fire frequency, the basal area remained relatively stable until the 1980’s followed by a slight increase for the rest of the century. Despite the differences in initial tree basal area both high fire frequency treatments had a similar a tree basal area from the 1920’s to the end of the period with the basal area remaining relatively stable year-to-year with apparently little impact from droughts. The TRAPS data from the Redrock site demonstrates a similar response as the low fire frequency treatments although basal area is slightly reduced.

In summary, this analysis indicates that high fire frequency maintains a low and stable tree population, while low fire frequency results in a higher tree basal area which is quite variable. When high basal area coincides with a major drought the tree population crashes. The flow-on implications of this crash for landscape function, biodiversity and enterprise productivity needs further investigation. The results from this work were presented at the North Beef Research Update Conference in March 2007 (Bray *et al.* 2007).

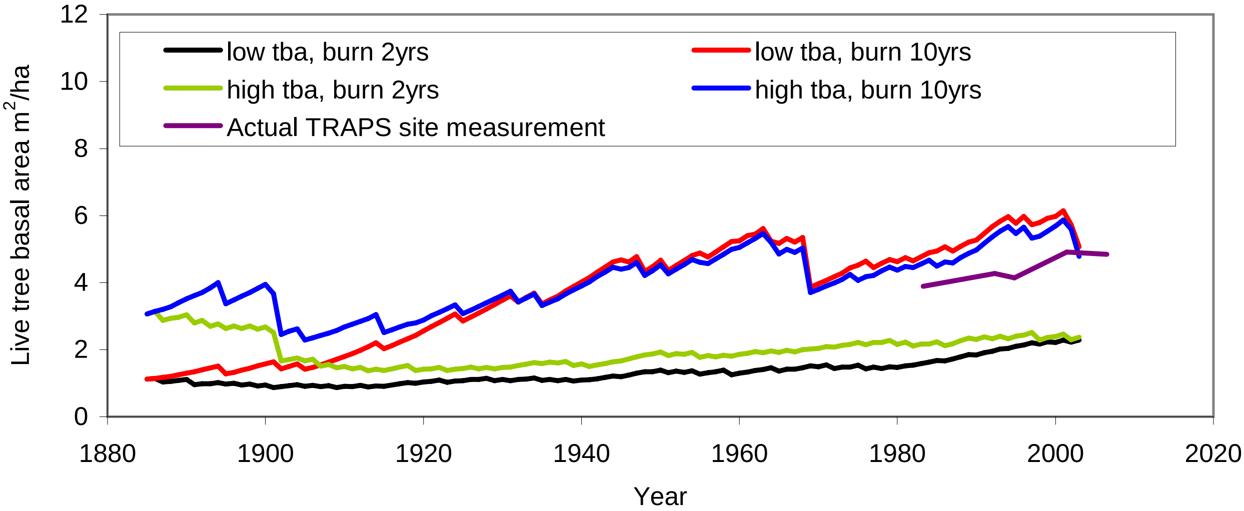

Figure 20 FLAMES model output after parameterisation for the Redrock TRAPS site. The actual site measurement is similar to the model prediction (Bray *et al.* 2007).

Other analyses as part of the CRC Tropical Savannas exercise include further investigation of the interaction between climate and fire on woodland dynamics and assessing a range of fire regimes on grazing enterprise profitability. Is there a profitable balance between the costs of fire strategies and the long term impact of tree basal area change on grazing productivity? The cost of burning potential forage is a major driver in this analysis. We expect this work to be finalised in 2007.

3.2.2 Aerial photo and ground based monitoring comparison

Aerial photo analysis (Fensham *et al.* 2003) and an analysis of the TRAPS ground-based woodland monitoring data (Burrows et al. 2002) estimated different magnitudes of woody vegetation change. We conducted a comparison of the two techniques at 28 common sites in an attempt to decipher the reasons for the discrepancy. Although the aerial photo technique and TRAPS technique were able to generate similar values for site basal area, the basal area change estimates were significantly different at common sites, 0.075 $m^2.ha^{-1}.yr^{-1}$ and -0.013 $m^2.ha^{-1}.yr^{-1}$ for the TRAPS and aerial photo techniques respectively (Table 2).

No single reason for the discrepancy was found, but a number of factors were identified with the aerial photo technique which may have contributed to the discrepancy, including;

- Effect of changes in photo-scale
- Failure to apply a back-transformation correction to biomass estimates
- Changes in photo quality during the record
- Changes in the relationship between canopy cover and basal area during the record.

Table 2 Basal area ($m^2.ha^{-1}$) and basal area change rates ($m^2.ha^{-1}.yr^{-1}$) predicted at 23 TRAPS sites (excludes long-term regrowth sites) using the TRAPS ground-based monitoring and aerial photography techniques at the initial comparison date T1 (av. 1983-84) and at the final comparison date T2 (av. 1997). Standard errors are in brackets. Change rates are determined as the average of the change rates for each site, which explains why a negative average change rate is possible despite the average basal area at T2 being higher than T1 for the aerial photography technique.

	TRAPS	Aerial photography technique
Basal area at T1	13.868 (1.235)	14.140 (0.902)
Basal area at T2	14.838 (1.511)	14.176 (1.152)
Basal area change rate T1 to T2	0.075 (0.042)	-0.013 (0.038)

The aerial photo technique assumes the cover to basal area relationship remains constant through time, whereas the relationship is likely to change with cycles of wet and drought periods. This factor may be the main reason the aerial photo technique appeared to have difficulty estimating basal area change at individual sites. This means it is difficult to confidently measure relatively small amounts of woody vegetation change over short (10 year) time periods using the aerial photo technique. The results of this analysis have been published in the Journal of Environmental Management (Fensham *et al.* 2007).

3.2.3 Satellite imagery and ground based monitoring comparison

The Statewide Land and Tree Study (SLATS) (NRW) have compiled a foliage projected cover series based on satellite imagery for the last 30 years. In cooperation with Tim Danaher, Joanna Kitchen (NRW) and Christina Playford (DPI&F Statistician), we undertook an exercise to compare woody vegetation change from the foliage projected cover series with the TRAPS ground-based monitoring data at common sites. This work is still in progress however some challenges and preliminary results are outlined below.

The SLATS data exhibits much more ‘seasonal’ variation than the TRAPS data. Therefore, splines have been generated through the SLATS data to smooth the variation and enable any trend in basal area to be discerned.

Figure 21 is an example of a site where this process appears to have worked well. However, for some other sites, the trend between the TRAPS and SLATS data appears different and the basal area estimates are offset (Figure 22). Reasons for these differences are being explored.

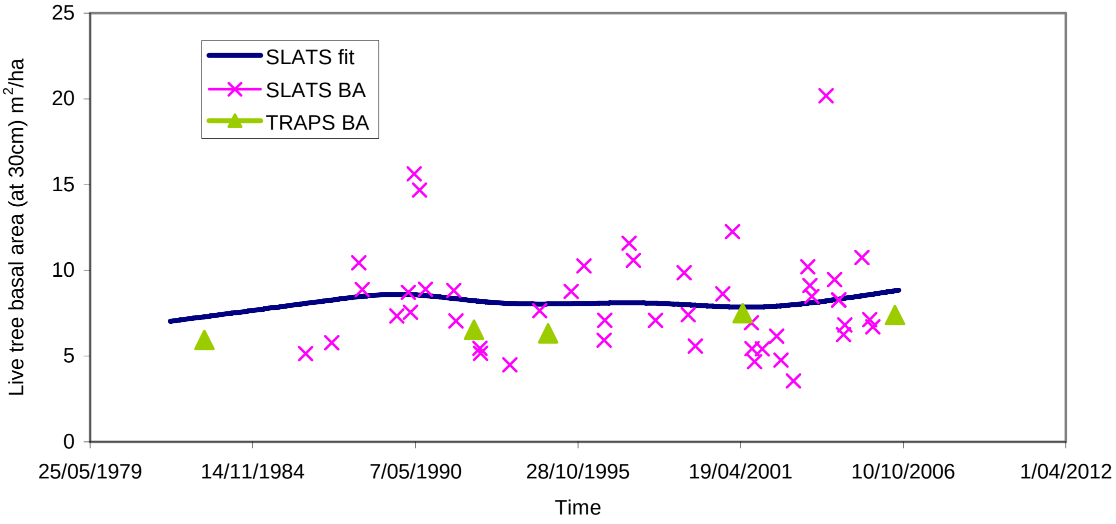

Figure 21 A site comparison of woody vegetation trends from SLATS and TRAPS datasets showing good agreement.

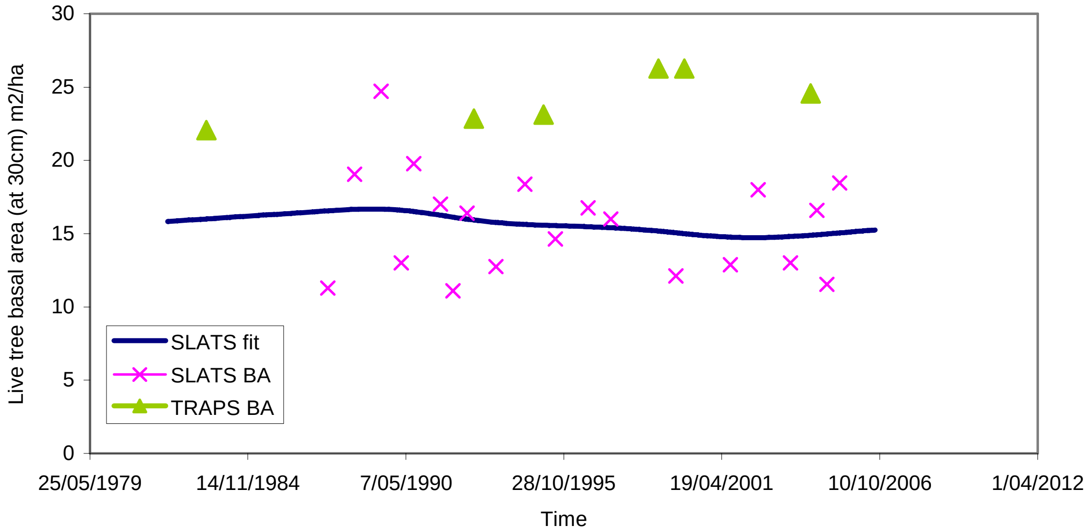

Figure 22 A site comparison of woody vegetation trends from SLATS and TRAPS datasets which do not show good agreement. The reasons for the difference are being explored.

3.2.4 Other data use

Madonna Hoffmann analysed stand structure data as part of a MSc degree. The thesis has been completed and the degree has been awarded.

Hoffmann MB (2006). Application of tree and stand allometrics to the determination of biomass and its flux in some north-east Australian Woodlands. Master of Applied Science, Central Queensland University.

Australian woodlands are diverse and variable, and have been subject to a range of management regimes since European settlement. Traditional forestry techniques for quantifying stand structure appear inappropriate for use in Australian woodlands, hence a reliable method of determining stand structure was required. This study successfully allocated one of six descriptive ranks, based on the proportion of trees in different tree height classes, to describe individual sites.

The Eucalyptus and Corymbia populations of ninety-five TRAPS woodland monitoring sites were grouped into the following descriptive ranks:

- Seedling (4% of sites)
- Early Growth (5%)
- Growth (54%)
- Early Mature (19%)
- Mature (14%)
- Mature without regeneration (4%)

At most sites the proportion of individuals, which were grouped into classes based on tree heights, indicated that stand structure has changed from a stable state (mature stand structure) to a less stable structure. This is usually due to a disturbance within the community, either man-made or natural (such as fire, drought or forestry practices), which alters recruitment, survival and mortality rates. In this study the sites ranked as Growth, Early Growth and Seedling all exhibit indications of change to different extents.

Sites that were ranked as 'Growth' exhibited a high proportion of saplings and young trees in the stand as a result of a past recruitment event and/or reduced competition within the stand. Similarly, sites ranked as Early Growth exhibited a high proportion of seedlings and saplings as a result of a disturbance. Sites that were ranked as 'Seedling' had no overstorey population of trees and usually represented stands that had recently been cleared or experienced a large decrease in the proportion of mature trees due to drought deaths. These stands will more than likely have a positive effect on future carbon fluxes as these trees increase in size, however they are likely to have a negative effect on future grazing productivity.

Sites that were ranked as ‘Early Mature’ are approaching a stable state, with a high proportion of trees in the larger size classes, usually from a disturbance event in their long-term history that had triggered a release of seedlings. Sites that were ranked as 'Mature' show tree size hierarchy, that is, a population of many seedlings are dominated by relatively few adolescent and large mature trees. In these communities the replacement of mature trees is not obvious and the dynamics within the stand appear to be stable. Sites that were ranked as 'Mature without regeneration' show no recruitment of young plants, and unless a future recruitment event occurrs within the stand these stands would be expected to decline. These stands may have a positive effect on future carbon fluxes as these trees continue to increase in size.

This thesis research demonstrated a successful methodology to describe the stand structure of the grazed woodland sites based on tree heights that will enable future analysis of stand dynamics.

TRAPS monitoring data has also been used in another six recent scientific publications and ten conference and workshop presentations (see Communications section below).

3.3 Communication

Six major activities were undertaken in this section on communication and education about woodland change and management considerations. The activities were:

- Co-operator packages
- Website
- Review of Grazing land management and Stocktake packages
- Glossy book
- Presentations
- Publications

3.3.1 Co-operator packages

Most TRAPS monitoring sites are on private or privately managed land requiring co-operation from land managers (91 landholder co-operators) to allow site access and maintain site integrity (ie. to stop removal of steel pickets). Co-operator packages have been designed as a project extension tool to help develop and maintain relationships and provide feedback to co-operators. Each co-operator package contains:

- a generalised component providing information on woodland management and implications;
- a customised component providing an update on the population trends within the co-operators monitoring site (DRYAD database output);
- a site photo series illustrating population trends, and;
- a management feedback form to assist with interpretation of population trends.

Co-operators receive a package following each site recording. For an example co-operator package see Appendix 9.2.

3.3.2 Website

Two web-pages were developed and are available on the DPI&F website.

http://www2.dpi.qld.gov.au/beef/18262.html (Figure 23)

http://www2.dpi.qld.gov.au/beef/18261.html (Figure 24)

One web-page gives an overview of the project, while the other web-page provides a brief overview describing the grazed woodlands and indicates some of the impacting factors on the woodlands and the value to the Queensland cattle industry

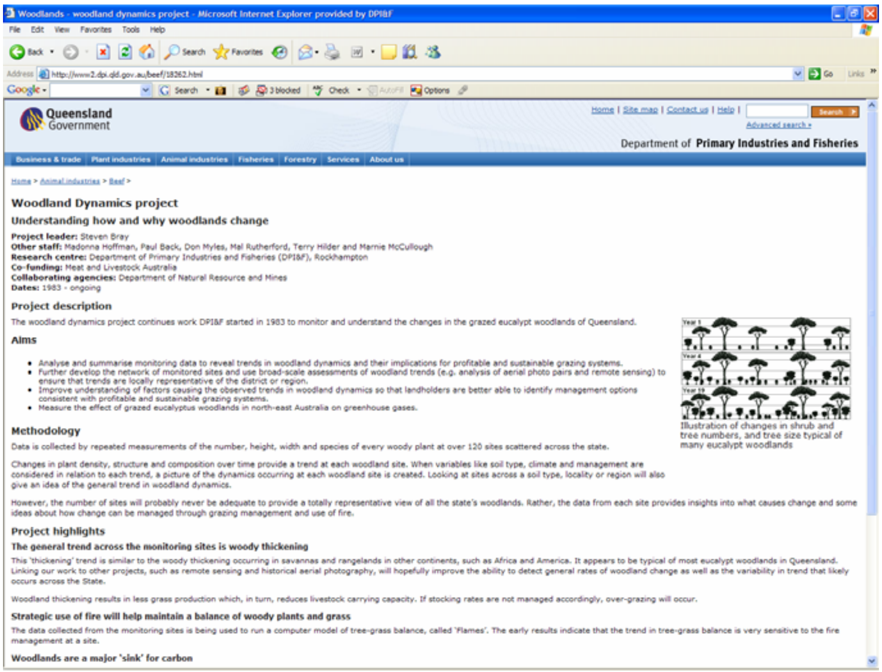

Figure 23 Web page on the Woodland dynamics project http://www2.dpi.qld.gov.au/beef/18262.html

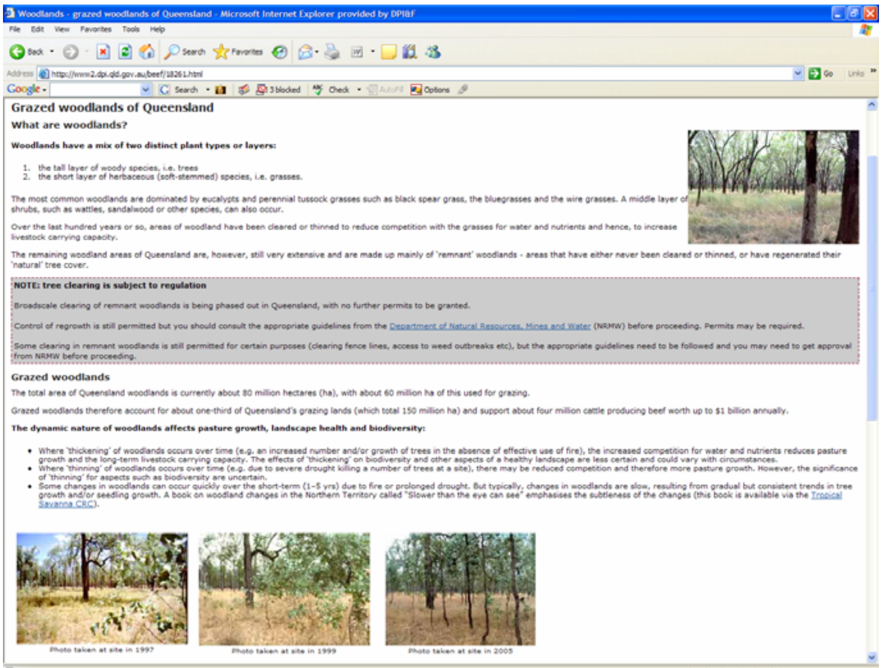

Figure 24 Web page on the Grazed woodlands in Queensland http://www2.dpi.qld.gov.au/beef/18261.html

3.3.3 Review of Grazing land management and Stocktake packages

The woodland and fire sections of the Grazing Land Management Education package and the Stocktake monitoring and feed budgeting package were reviewed. The Stocktake package provides a good structure by which landholders can monitor their own woodlands in relation to land type by using photo sites and the bitterlich technique (tree basal area measurement). The package also incorporates some analysis of the impact of changing tree density on pastoral production. The Stocktake package is a useful framework in which to further develop a woodland monitoring tool for land managers. Upon our review's recommendations, a dendrometer (an instrument to measure tree basal area) has been included in each Stocktake package to improve tree basal area assessment.

3.3.4 Extension booklet

A draft publication has been compiled and has been reviewed. MLA and the DPI&F publications group have suggested some changes which are currently being incorporated into the publication. In consultation with MLA the 'Advanced print ready publication draft' will be ready in 2007.

3.3.5 Presentations

The TRAPS woodland monitoring results have been presented at ten conferences and workshops.

The Changing Woodlands. Steven Bray Paul Back, Madonna Hoffmann, Michael Yee, Don Myles, Mal Rutherford, Terry Hilder, Marnie McCullough, Christina Playford. Landcare conference Barcaldine, 2005.

Queensland's remnant woodlands have changed, leading to an increased store of biomass carbon. Steven Bray, Evelyn Krull, Mal Rutherford and Ben Harms. Greenhouse 2005, Melbourne. November 2005,

Vegetation Change since Captain Cook. Steven Bray Paul Back, Madonna Hoffmann, Michael Yee, Don Myles, Mal Rutherford, Terry Hilder, Marnie McCullough. Rockhampton seminar series, June 2005

TRAPS - The DPI&F's grazed woodland measurement and monitoring program. Rockhampton seminar series. Paul Back, April 2006.

The Changing Woodlands. Steven Bray Paul Back, Madonna Hoffmann, Michael Yee, Don Myles, Mal Rutherford, Terry Hilder, Marnie McCullough, Christina Playford Presentation to CQ vegetation management officers, October 2005.

Increasing tree cover in grazing land - A case study from Queensland. Steven Bray, Evelyn Krull, Ben Harms, Nathalie Baxter, Mal Rutherford, Michael Yee, Lex Cogle. International Geographical Union conference, Brisbane, July 2006.

Increasing tree cover in grazing land - A case study from Queensland. Steven Bray, Evelyn Krull, Ben Harms, Nathalie Baxter, Mal Rutherford, Michael Yee, Lex Cogle. CRC Greenhouse Accounting briefings in Sydney and Melbourne. May and June 2006.

Weedy Grasses, native trees: Two productivity issues affecting landholders. Steven Bray and Mal Rutherford. Burnett Mary Regional Group Science Symposium, Hervey Bay. February 2007.

Comparison of woody vegetation change datasets from the grazed woodlands of central Queensland. Steven Bray, Adam Liedloff, Anna Sim, Paul Back, Garry Cook, Madonna Hoffmann. Northern Beef Research Update Conference. Townsville, March 2007.

Comparison of woody vegetation change datasets and potential opportunities and risks for carbon trading. Steven Bray. Presentation to South West NRM Board and staff. March 2007.

3.3.6 Publications

Data and expertise gained from the monitoring network has been incorporated into seven recent papers.

1. Two techniques (TRAPS methodology and aerial photo analysis) were compared to determine reasons for differences in live basal area change estimates (Fensham *et al.* 2007).
2. Changes in root:shoot ratios along a rainfall gradient in poplar box were reported. Above and below-ground tree biomass was sampled adjacent to monitoring sites. Monitoring data was utilised to estimate site tree basal area and aboveground biomass on which the ratios were based (Zerihun *et al.* 2006).
3. Vegetation change was assessed using soil carbon isotopes. The paper incorporated an allometric between stand tree basal area at 30cm and 130cm height developed at woodland monitoring sites (Krull and Bray 2005).
4. General predictive equations have been developed for estimating above-ground tree biomass in northern Australia. This paper incorporated data collected from trees neighbouring the long term monitoring sites (Williams *et al.* 2005).
5. The impact of fire on population density and canopy area of currant bush (*Carissa ovata*) in central Queensland and its implications for grazed woodland management (Back 2005).
6. Comparison of woody vegetation change datasets from the grazed woodlands of central Queensland (Bray *et al.* 2007).
7. Change in tree size class distribution. Masters thesis (Hoffmann 2006).

Other papers in-preparation include:

1. Results of the Wondabah clearing trial (Back).
2. Results of the Wigton wattle burning trial (Back).
3. Paper assessing the economics of using fire to manage woodland density and interactions with climate (Cook, Holmes, Liedloff, Bray).

4 Current and future prospects for the TRAPS monitoring network

4.1 Network status in 2007

4.1.1 Significance of the TRAPS monitoring network asset

The TRAPS monitoring network is one of the few long-term datasets available on which to base woodland management models and decisions. The network has already shown its importance in the carbon debate and implications for grazing industries (Burrows 2002; Burrows *et al.* 2002; Henry *et al.* 2002). The carbon/greenhouse issue was not even a consideration when the network was first established, but demonstrates the importance of long-term rigorous monitoring compared to short-term investigations particularly when measuring relatively slow change.

4.1.2 Field sites, co-operator relationships.

There are currently 111 active TRAPS woodland monitoring sites (40 ‘old’ sites established 1982-87 and 71 ‘new’ sites established 1997 -2006). Seventy-two sites (61 in ‘remnant’ vegetation and 11 ‘non-remnant’ sites) have been re-sampled over the last 3 years. All the co-operators have been contacted and are aware of the site located on their property and have received a report for that site. It is important that good relations are maintained with co-operators with, a least, annual contact.

These sites are permanently marked with steel pickets and a GPS location recorded.

4.1.3 ‘DRYAD’ Database

The database is up to date. The database is located on the DPI&F Rockhampton server with back-ups on CD and personal PCs. The ‘DRYAD’ database currently includes queries to extract data for data analysis to answer ‘commonly’ asked questions and other collaborative analyses.

As with all databases, maintenance will be required to keep it up to date and secure into the long term.

4.1.4 Labour and financial resource availability

DPI&F research operates using an investor/provider model. At the end of a major project, such as the current project, the work is reviewed and a compelling case based on current priorities and external support needs to be collated for substantial DPI&F investment to continue (eg. a major field sampling exercise). In the meantime, DPI&F officers commit to maintaining contact with co-operators via an annual letter, maintaining the ‘DRYAD’ database, and extracting data for collaborative analyses.

The following section highlights some future options for the current woodland monitoring network.

4.2 Future options for the 'TRAPS' monitoring network

The TRAPS monitoring network has provided a strong scientific basis for past projects and has potential to be the 'backbone" dataset for future projects involving issues related woody vegetation on grazing land in Queensland. The TRAPS woodland monitoring network is not an end in itself. It is the associated analysis and collaboration to answer specific questions based on solid scientific observation that is the 'true' return on investment.

Future investment in new projects by DPI&F is based on ensuing project alignment with current DPI&F, Government and external agency priorities. Some current published priorities where projects based on the TRAPS monitoring network could make a significant contribution include:

- 'Maximise the economic potential of Queensland's primary industries on a sustainable basis' is the mission in the **DPI&F 2006-2011 Strategic Plan**. This could involve determination of an economic balance between livestock production, woody vegetation products (such as timber or carbon) and water.
- 'Vegetation management and woodland thickening' was identified as a high ranking R&D issue in the **MLA Northern Beef Program – Livestock production research and development Strategic Plan 2006-2011**. 'Cost-effective management of woody vegetation' is a desired outcome identified under the Grazing Land Management, Key Research Area within the plan. Emerging issues and challenges of greenhouse gas emissions and climate variability and climate change were also noted. Fire management was identified as important in North Queensland.
- 'Explore opportunities to use market based approaches such as carbon trading and environmental off-set.' **Blueprint for the Bush**. Understanding the potential for carbon accumulation in grazing land and the risks associated with storing that carbon over 70-100 years will be important issues for carbon trading in grazing land.
- 'Better knowledge of climate and ecosystem interactions is important towards managing natural resources sustainability under changing climate conditions.' **Climate Change: the challenge for natural resource management NRW**. Long term on-ground monitoring will be crucial to improving knowledge of ecosystem changes with climate. Remote sensing technology will not be able to decipher changes in species dominance for example.
- Enhance biosequestration opportunities in agriculture. **National Agriculture and Climate Change action Plan 2006-2009.** Woodland monitoring will be important for measuring success and risks involved in long term carbon storage.

These priorities focus on economic sustainability, carbon trading and climate change which reflect the current debate and interest in these issues. Of importance to note is that the only reason the TRAPS woodland monitoring network has a role to play in helping to address these recent prioritised issues is that the sites have been established and monitored over the last 25 years, highlighting the need for ongoing, continuous commitment to basic long term vegetation monitoring projects.

Remote sensing is seen as an alternative to on-ground vegetation monitoring as analysis can be conducted at the regional-scale, however an important part of remote sensed product development is the calibration or 'truthing' against reliable on-ground data.

4.2.1 Interaction and collaboration during remote sensed product development

Remote sensing will be an increasing important technology for monitoring landscapes in the future (eg. SLATS). However remote sensing requires permanent on-ground monitoring sites against which to calibrate or compare output. This is particularly important when discerning relatively small changes over short time periods (eg. 5-10 years).

Permanent monitoring sites are essential for the development of remote sensing products by providing a long term calibration dataset. This is important because:

- Remote sensing generally relies on spectral image capture using electronic sensors often on a satellite platform or historically, photographic film on an aircraft platform. Satellite sensor and aerial photography technology has changed over time. This has led to a number of issues which impact on the consistency of the record over time. Sensor output can drift over the life of the sensor and require ongoing calibration, often back in time as new uses and analyses are developed from historically captured images. Sensors also 'die' and are replaced over time, therefore the remote sensed record needs to have the signal from sensor change removed from the long term record. This is also complicated by advances in technology and changes in sensor resolution. On-ground monitoring plots with known change can help calibrate or cross-check the remote sensed record over time.
- The relationship between tree basal area and canopy cover changes over time particularly in relation to major drought events. Ground-based sites a because they measure the more stable basal area of tree trunks enables discrimination between changes in tree cover due to tree size and density from seasonal effects on canopy cover.
- Remote sensing will have difficulty assessing change in tree species over time or a change in tree size class distribution. Presently woodland community dynamics can only be assessed with on-ground, long-term monitoring sites.

The current project has collaborated with two remote sensing product developers. These were aerial photography assessment (Rod Fensham EPA) reported in section 3.2.2 and with the SLATS imagery (Tim Danaher and Joanna Kitchen, NRW) reportedin section 3.2.3. The SLATS collaboration will continue after the end of this project to finalise the analysis.

The SLATS imagery is also being used to assess changes in ground layer condition at the property and regional scale. This product appears to work when there is minimal tree cover, however it is not currently reliable when tree cover is present. To eliminate this problem, areas with tree cover are 'masked out' and the ground layer is not monitored in these areas, essentially eliminating 60-80 Mha or a third of Queensland's grazing land from the analysis. There is potential to use the TRAPS woodland monitoring network to try and develop new methodology to monitor the ground layer within wooded systems or to at least compliment the remote sensed ground layer condition monitoring in open areas. Discussions have begun and will be ongoing with Bob Karfs and Terry Beutel DPI&F.

4.2.2 For and against arguments for six future TRAPS network options

Six options are available for the future of the TRAPS woodland monitoring network; status-quo, expansion, rationalisation, 'mothballing', giving-away or closing-down. The arguments for each option are discussed in Table 3. Section 4.2.3 provides an estimate of resources required to maintain the 'Status-quo" option.

Based on the potential for new innovative projects (under the priorities listed above) requiring rigorous woodland monitoring data, our view is that the status-quo or expansion options are the most logical at this point in time. The method of expansion may be on a project basis or statewide basis. Examples of a project basis expansion include a particular interest in carbon storage in mulga communities or a particular natural resource body may have an interest in riparian woody vegetation in coastal catchments or the channel country. These types of projects would lead to more sites being established in focused areas of interest to compliment the current sites.

The other options leading to a down rating (rationalisation and mothballing) or closing-down of the network do not appear sensible at present, particularly as many questions are being asked relating to carbon storage issues and climate change on woodland ecosystems.

Table 3 For and against arguments for six future options for the TRAPS woodland monitoring network.

Future option	Definition and considerations	For	Against
Status-quo	Maintain the network. Network remains within DPI&F. Seek institutional funding and collaborative external support to maintain the network and maybe incorporate monitoring of other aspects in woodlands (eg. biodiversity, hydrology, landscape function, QGRAZE).	Maintain and build on a significant asset. Past investment is not lost. The network is ready to help address new issues as they arise. On-going testing of new technologies "eg. remote sensing products" will be required. DPI&F has 'Champions' with a passion for the monitoring network.	Ongoing resources required.
Expansion	Maintain existing sites and expand the network to improve coverage of the woodlands in Queensland. Network remains within DPI&F. Seek collaborative and institutional funding. Maybe incorporate monitoring of other aspects in woodlands (eg. biodiversity, hydrology, landscape function, QGRAZE).	The monitoring network better represents the woodlands in Queensland. Improve understanding of regional and land type differences and temporal impacts of climate change. Able to better satisfy monitoring commitments from a national perspective (eg. ACRIS). Builds on a significant asset. DPI&F has 'Champions' with a passion for the monitoring network.	Increased resources required. May not be viewed as core business of DPI&F. Requires substantial additional external support and commitment. Additional staff resources required with a commitment to long-term input. Will take time for new sites to generate a 'history' and become 'useful'.
Rationalisation	Reduce the number of sites to only a few 'high priority sites' which are 'regularly' visited. Network remains within DPI&F.	Reduced resource expenditure. May be focus on a small region or land type.	Reducing the number of sites reduces the representativeness of the monitoring network and questions may be raised over what it does

Future option	Definition and considerations	For	Against
			represent. How do you prioritize which sites and regions will no longer be monitored. Ongoing funding still required.
Mothballing	Put the whole monitoring network on hold. Archive current data. Hope sites still exist if there is interest in re-sampling in the future. Network remains within DPI&F.	Minimal resource expenditure. Network can potentially be resurrected if the need and interest arises in the future.	Minimal benefit/output from any resource expenditure. Contact with co-operators not maintained and many sites potentially lost (eg. pegs removed). Poor record and understanding for reasons for changes at sites.
Give-away	Hand the monitoring network and data over to another department (eg. NRW, EPA) or institution to maintain and manage as they see fit.	No longer a resource liability for DPI&F. Other agencies have legislative responsibility for native vegetation management in Queensland. Could be expanded to cover un-grazed woodlands.	Long-term experiments and monitoring networks require a long-term commitment and passion of an organisation and individual passionate ‘champions’. These are probably lacking for the long-term viability of the network in other institutions. Co-operators may not want to collaborate with other institutions particularly if they have regulatory power over them. DPI&F loses another link to landholders in the bush.
Closing-down	Close the network down. Write-up data to date. Remove pegs and inform co-operators they are no longer needed.	No longer a financial or labour resource burden on DPI&F. Remote sensing by someone else can take over landscape monitoring.	Short-sighted. Future issues will arise that have not yet been considered which may have a need for the data (greenhouse/carbon issues were not considered important when the sites were established). At least leave the pegs in place in case someone in the future has a use for the sites.

Future option	Definition and considerations	For	Against
			Remote sensing needs ground-truthing and is at a much larger scale. There is little or no differentiation between woody plant species.

4.2.3 Investment required for maintaining the existing network

The annual investment required to maintain the existing network (‘status-quo’) is presented in Table 4. Assumptions include; 120 active sites sampled on average every 4 years (30 sites per year) with staff shared between this and other projects. More detailed budgeting may alter this calculation. The average 4 year sampling interval is suggested based on experience. Shorter timeframes pick up more subtle changes but often little change has occurred. Longer timeframes have potential to miss the impact of significant events eg. a major drought may have killed some trees but the woodland has since regrown back to the same basal area. Analysis of site basal area would indicate the woodland had been stable, when in fact it has been highly variable. Also, the monitoring network would have reduced usefulness for comparisons with remote sensed products if the sampling interval is too long, particularly as many remote sensed products are being developed for yearly or biennial assessments.

Table 4 Annual investment required to maintain the existing TRAPS woodland monitoring network.

	Annual FTE	Expenditure
Field work (site maintenance and data checking)	0.7 FTE (2 people, average 2.5 sites per 5 day week -12 field weeks per year).	Salary $ 56,000 Travel expenses $ 18,000 Vehicle and equipment $ 20,000 Office and computer expenses $ 4,000
Database management, data analysis, preparation and distribution of annual co-operator communications, website up-keep	1.0 FTE (not necessarily one person).	Salary $ 79,000 General expenses $ 5,000 Office and computer expenses $ 5,000
Total	1.7 FTE	$187,000

4.3 Key recommendations

1. The DPI&F to accept an ongoing funding commitment for the long-term ‘TRAPS’ woodland monitoring project (approximately 120 sites) including staff and operating resources needed to maintain the base data collection and data storage, which is supported and facilitated by industry. External project funding could be sought to conduct specific analyses and expand the network in focused areas of interest.

2. Collaboration with remote sensed product developers to continue, particularly the NRW SLATS group and DPI&Fs ground cover monitoring project.

3. Design future collaborative projects addressing the priority issues of climate change, carbon trading and woodland management within the context of profitable and sustainable enterprises.

4. That the ‘closing-down’ or ‘mothballing’ of the TRAPS woodland monitoring network be recognised as unreasonable options by DPI&F and industry and counter productive to long term beef industry productivity.

5 Success in Achieving Objectives

5.1 Success in Achieving Objectives

5.1.1 Success in Achieving Objective 1

Establish a verifiable, comprehensive and on-going system for quantifying and understanding change (trends) in woodland structure and composition across the pastoral woodland communities of Queensland by 31 October 2006.

Four major activities were undertaken to satisfy this objective. These were:
- development of the ‘DRYAD’ database to aid in data storage, handling and improved output generation;
- assessment of the representativeness of the current sites and selection of new sites to fill gaps in the network.
- re-sampling of current TRAPS woodland monitoring sites;
- development of a photo pairs database to record past, present and future photo sites.

A major advance for the project has been the development of the woodland dynamics database, DRYAD. A process has been developed to enable efficient data entry, storage and data extraction. The database can now efficiently produce output on rates of change in tree basal area, species number, shrub cover and biomass. Climate data can also be integrated into the database for each site. Known management information and future management data (extracted from landholder feedback) can now be incorporated into the database.

A GIS (geographic information system) site representativeness analysis was conducted to test the representativeness of the current monitoring sites, identify gaps in the monitoring network and to select high priority locations in which to establish new sites. The proportion of sites representing classes within the attributes; broad vegetation group, soil type, tree basal area, and wettest quarter rainfall and temperature were compared to the proportion of area in the whole study region. Two networks of new sites were developed. One network corrects the most deficient attribute classes with a minimum number of sites (17 high priority new sites). The second network (55 sites) fills remaining spatial gaps between the established and 17 high priority proposed sites.

The current TRAPS woodland monitoring sites were assigned a priority for re-sampling using a desktop exercise This prioritisation exercise was based on time since last recording and site integrity. Seventy-two sites (of 111) have since been re-recorded during this project.

A photo pairs database has also been developed to catalogue past, current and future photo sites. This database has undergone testing and a manual has been written. Fifteen photo pairs are currently in the database.

5.1.2 Success in Achieving Objective 2

Produce tools and models to extrapolate and predict patterns of woodland change in the pastoral woodland communities by 31 October 2006.

Four activities were undertaken to satisfy this objective. These were:

- Simulation modelling exercise
- Comparison of aerial photography and ground based monitoring techniques.
- Comparison of satellite imagery and ground based monitoring techniques.
- Other data use for thesis, scientific papers and presentations.

The project developed formal links with Garry Cook, Adam Liedloff (CSIRO Darwin), Bill Holmes, Marnie McCullough and Chris Chilcott (DPI&F) through the CRC for Tropical Savannas, Dynamic Savanna project which bought together detailed tree dynamics data, the FLAMES fire and landscape model, economic expertise, GRASP model output and grazing land management principles. The objective of this modelling exercise was to use ecological and economic modelling to predict and communicate the potential effectiveness of management interventions aimed at modifying woody vegetation structure on grazing properties. The analyses investigated the interaction between climate and fire on woodland dynamics and assessed a range of fire regimes on profitability. Some results were presented at the North Beef Research Update Conference (Bray *et al.* 2007) and a scientific paper is currently in preparation.

The Statewide Land and Tree Study (SLATS) (NRW) have compiled a foliage projected cover series based on satellite imagery for the last 30 years. In co-operation with Tim Danaher, Joanna Kitchen (NRW) and Christina Playford (DPI&F Statistician) we undertook an exercise to compare woody vegetation change from the foliage projected cover series with the TRAPS ground-based monitoring data at common sites. This work is still in progress, however preliminary results are promising.

Aerial photo analysis (Fensham *et al.* 2003) and an analysis of the TRAPS ground-based woodland monitoring data (Burrows et al. 2002) estimated different magnitudes of woody vegetation change. We conducted a comparison of the techniques at 28 common sites in an attempt to decipher the reason for the discrepancy. The exercise highlighted that there are some issues and potential bias in the aerial photography technique at the paddock scale and over short (10 year) time frames. Therefore the aerial photography technique should not be the sole technique used to prove or disprove woodland change at these scales. A scientific publication has been published (Fensham *et al.* 2007).

Data from the TRAPS monitoring network has been used in 7 scientific publications and in 10 conference and workshop presentations.

5.1.3 Success in Achieving Objective 3

Produce tools and practices for beef producers to monitor and manage woodland change by 31 October, 2006.

Six activities were undertaken to satisfy this objective focusing on communication and education about woodland change and management considerations. The activities were:

- Co-operator packages
- Website
- Review of Grazing land management and Stocktake packages
- Glossy book
- Presentations
- Publications

Co-operator packages have been designed as a project extension tool. These packages help develop and maintain relationships and provide feedback to the 91 co-operators involved in the project. Each co-operator package contains:

- a generalised component providing information on woodland management and implications;
- a customised component providing an update on the population trends within the co-operators monitoring site (DRYAD output);
- a site photo series illustrating population trends, and;
- a management feedback form to assist with interpretation of population trends.

The woodland and fire sections of the Grazing Land Management Education package and the Stocktake monitoring and feed budgeting package were reviewed. The Stocktake package provides a good structure by which landholders can monitor their own woodlands in relation to land type by using photo sites and the bitterlich technique (tree basal area measurement). The package also incorporates some analysis of the impact of changing tree density on pastoral production. The Stocktake package is a useful framework for landholder woodland monitoring.

The glossy publication has been compiled and is being reviewed. The book discusses the drivers and impacting factors on woodland dynamics management. The book also outlines a simple woodland monitoring technique similar to the Stocktake package.

Data and expertise gained from the TRAPS monitoring network has also been used in 7 scientific publications and in 10 conference and workshop presentations including the 2005 Landcare Conference and 2007 Northern Beef Research Update Conference attended by a large number of landholders, extension officers and regional body personnel.

6 Impact on Meat and Livestock Industry – now & in five years time

The impact of this project has been in communicating our understanding of grazed woodland change based on sound scientific data and highlighting how this change can impact on pastoral livelihoods and broader concerns of greenhouse/carbon and climate change.

The current project has built on the substantial historical asset of the TRAPS woodland monitoring network which has been progressively established since the early 1980's. The current project through conference/workshop presentations and publications has continued to raise the awareness of government/policy and the community about the issue of woodland dynamics and the implications from a grazing enterprise and a greenhouse/carbon perspective. Woodland change (thickening and thinning) has now been widely recognized as an issue particularly in relation to landscape carbon accounting. The future benefit from this recognition we expect will result in further projects to determine the potential opportunities, benefits and risks involved in potential carbon trading schemes. Who benefits, who pays and guidelines for carbon trading are still subject to much discussion and uncertainity, but there may be future opportunities for the 'livestock' industries in the next 5-10 years as these issues are resolved.

The current project has 'modernised' the TRAPS woodland monitoring network through the development of the DRYAD database and reassessment of sites. This places the network in a strong position to make significant contribution to future climate change and greenhouse/carbon projects which will have a requirement for rigorous long term on-ground datasets, most likely in combination with remote sensed products.

The current project has had a strong collaborative focus which we believe has had a significant positive impact on research direction and understanding of pastoral production in grazed woodlands. Not only has the collaboration brought together 'experts' in remote sensing, simulation modelling and carbon accounting to address issues on grazing land but the information and perspectives have been shared with these 'experts' so they have a better understanding of the issues and perspectives of the grazing industries, rather than for example solely from an environmental/ecological perspective. This was particularly relevant for the FLAMES fire and vegetation simulation modelling exercise where we incorporated grazing, grazing land management principles and economic assessments into a simulation model used to assess woody vegetation dynamics in northern Australia. This improvement in the model will have flow-on impacts for future analyses as the implications-of and impacts-on grazing industries can be assessed while investigating future tree dynamics research questions.

Remote sensing technology provides a powerful tool to observe changes in tree cover at the landscape scale over time. Good knowledge of the current state and trend in grazing land may not always be 'good news' for land managers, however it is important that results from analyses are based on real, verifiable data, which can be much better than the perceptions otherwise. Long term vegetation monitoring datasets like the TRAPS woodland monitoring network have an important role in the calibration and testing of new remote sensing technology. On-ground monitoring can be compared with the remote sensing technology results to ensure it is measuring what it is purported to be measuring. If the results from remote sensing and ground-based monitoring are divergent then this difference needs to be addressed. For example this project compared woodland change estimates using an aerial photography technique with ground-based measurements at TRAPS sites

(Fensham *et al.* 2007). The exercise highlighted that there are some issues and potential bias in the aerial photography technique at the paddock scale and over short (10 year) time frames. Comparison with the SLATS satellite imagery products is continuing.

Key insights into woodland dynamics have been included in the Grazing Land Management and Stocktake packages. These education tools ensure land managers are aware of the opportunities and costs surrounding woodland dynamics. This understanding will help stimulate innovative management to economically address woodland change within the provisions of the Vegetation Management Act 1999.

It is important that the meat and livestock industries continue to ensure that one dataset or agenda is not the sole source of information for issues impacting on the land and vegetation assets driving their livelihood. Ensuring and stimulating cross-checks and interaction between project teams and approaches is important to ensure good long term outcomes for the meat and livestock industries and wider community expectations.

7 Conclusions and Recommendations

The woodlands have, are and will continue to change. Understanding the magnitude and impact of this change is important for landholders managing their own business asset, the community and government. Industry has a role to ensure there are cross-checks and interaction between various project teams and approaches (particularly between remote sensing, modelling and ground based monitoring) to ensure good long term outcomes for the industry and the community.

Key recommendations from the project are:

1. The DPI&F to accept an ongoing funding commitment for the long-term 'TRAPS' woodland monitoring network (approximately 120 sites) including staff and operating resources needed to maintain the base data collection and data storage, which is supported and facilitated by industry. External project funding could be sort to conduct specific analyses and expand the network in focused areas of interest.

2. Collaboration with remote sensed product developers to continue, particularly the NRW SLATS group and DPI&Fs ground cover monitoring project.

3. Design future collaborative projects addressing the priority issues of climate change, carbon trading and woodland management within the context of more profitable and sustainable beef enterprises.

4. That the 'closing-down' or 'mothballing' of the TRAPS woodland monitoring network be recognised as unreasonable options by DPI&F and industry and counter productive to long term beef industry productivity.

5. The project team to continue to present the results and understandings from the TRAPS woodland monitoring in a range of forums including conferences and workshops.

6. The project team to continue analysis of the data acquired over the last few years and publish the results in a scientific publication.

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9 Appendices

9.1 Appendix 1 - Representativeness testing of TRAPS site network and new site selection

Michael Yee and Steven Bray

9.1.1 Objectives

This report satisfies part of the criteria for objective 1of the project. Establish a verifiable, comprehensive and on-going system for quantifying and understanding change (trends) in woodland structure and composition across the pastoral woodland communities of Queensland.

The aims were to:
- Determine the region represented by the current TRAPS sites.
- Identify the location of gaps in the area represented.
- Identify where new sites should be located to fill the gaps and improve representativeness of the monitoring network.

9.1.2 Overview

A GIS analysis process was carried out to test the representativeness of the existing TRAPS site network against the remnant woodland areas of Queensland. There are a total of 108 TRAPS sites, of which 18 lie in non remnant vegetation areas. The proportion of sites representing classes within the attributes; broad vegetation group (BVG) (Table 1), soil type, tree basal area (BA), and wettest quarter rainfall and temperature were compared to the proportion of area in the whole study region. The results were used to determine if there were any gaps in the network and where new sites should be located for maximum benefit in correcting deficiencies.

Two networks of new sites were developed. One network corrects the most deficient attribute classes with a minimum number of sites (17 sites). This number of sites could potentially be established under current funding arrangements. The second network (grid sites) fills remaining spatial gaps left by the original TRAPS sites and the 17 new sites. It represents an ideal woodland monitoring network given improved resources.

Software used was ArcView 3.2, ArcGIS 8.3 and 9.

9.1.3 Determining representativeness of the current TRAPS sites

GIS layers generated
Study area
A study area boundary was digitised from three overlayed themes; a Queensland rainfall isohyte layer, a latitude/longitude graticle of 1 degree division and Queensland state outline. The study area boundaries are shown in figure 1.

Vegetation

Broad vegetation groups (BVG) were identified from the *1:100 000 Survey and Mapping of Vegetation Communities and Regional Ecosystems of Queensland*, V4.2 (Queensland Herbarium 2003) digital map. The BVGs were derived from only the primary regional ecosystem for each polygon. This layer was clipped with the study area layer to give BVGs in the study area.

Areas were calculated for each BVG by projecting to an Albers equal area projection (central meridian 146.0, standard parallels –13.166667 and –25.833333, datum GDA 1994).

A vegetation mask (figure 2) was created for use in other analysis operations. Non remnant (cleared) areas, grassland (BVG= 29) areas and areas with no BVG classification were removed from the mask.

Soil

The Queensland salinity hazard assessment map (Brough 2001) was used to obtain Australian soil classification groups for the study area by overlaying it with the study area/vegetation masks. This layer was projected and areas of soil groups calculated. Soil type at TRAPs sites were determined according to the polygon in which each site was located in.

Rainfall and temperature

Table 1. The description of broad vegetation groups used in the analysis. Source: Queensland Herbarium (2003).

BVG	Description
9	Moist to dry open forests to woodlands on coastal lowlands and ranges
10	Moist to dry open forests to woodlands mainly on basalt areas
11	Dry to open woodlands, mostly on shallow soils in hilly terrain (most extensive on sandstone and weathered rocks)
12	Dry to open woodlands on undulating to low hilly terrain dominated by *Corymbia citriodora*. Often includes other species such as *Eucalyptus crebra, E. acmenoides, E. fibrosa* subsp. *Fibrosa, Angophera leiocarpa* and *C. trachyploia* (various geologies).
13a	Woodlands and open woodlands dominated by *E. culleni, E. melanophloia, Corymbia erthyrophloia, E. white*i to *E. persistens* or *E. tardecidens*
13b	*E. micorneura* woodland on shallow soils on rolling hills
13c	Moist to wet forest to woodland at moderate to high altitudes dominated by *Eucalyptus acmenoides* and *Corymbia intermedia,* OR, on heavier soils, dominated by *E. tereticornis, C. intermedia* and *Lophostemon suaveolens*. Other common species may include *L. confertus, C. trachyphloia, Syncarpia glomulifera, E. montivaga, E. resinifera, E. suffulgens, E. fibrosa, E. cloeziana, Allocasuarina torulosa, A. littoralis, Grevillea banksii, Acacia melanoxyon, Acacia flavescens, Banksia integrifolia var. compar,* and *Xanthorrhoea spp.*
13d	Dry woodlands, often on coarse sandy soil, on undulating to hilly terrain. Dominated by species such as *Eucalyptus acmenoides, Angophora leiocarpa, Corymbia trachyphloia, C. intermedia*, and often also including *E. crebra, C. citriodora, E. decolor, E. eugenioides, E. longirostrata, Syncarpia glomulifera, E. montivaga, C. gummifera*. A heathy shrub layer is frequently present.
13e	Woodlands and open-woodlands dominated by *Eucalyptus crebra* (sens lat), on hilly terain. Includes *E. drepanophylla.*
15	**Woodlands and tall woodlands dominated by *Eucalyptus tetrodonta,* and/ or *Corymbia nesophila* and/ or *E. phoenicea***
17	**Eucalyptus dominated open-forest and woodlands drainage lines and alluvial plains.**
18a	*Eucalyptus populnea and E. melanophloia.dominated wooodlands to open- woodlands in western areas on alluvium sand plains and footslopes of hills and ranges.*

18b	Dry woodlands to open- woodlands, mostly on alluvium or flat to undulating plains with sandy surfaced texture contrast soils. Dominated by species such as *E. chloroclada, Angophora leiocarpa*, often with dense *Allocasuarina luehmannii* understorey. Includes *E. populnea* and/or *E. melanophloia* (group 11a) where subdominant with other species. *E. persistens, C. plena, C. dallachiana* in DEU and *E. cullenii* in EIU.
18c	*E. crebra* (sens lat) woodlands on flat to undulating plains. Includes *E. drepanophylla.*
18d	Woodlands and open-woodlands dominated by *Eucalyptus chlorophylla, E. microtheca* or *E. acroleuca* on texture contrast soils or *E. leptophleba* on heavy soils on rolling plains
18e	*E. microneura* woodlands on alluvium and associated flats - LZ 5
18f	*Eucalyptus whitei* on sand sheets in Desert Uplands
19	**LOW OPEN-WOODLANDS WITH USUALLY SPINIFEX UNDERSTOREY (mainly northwest Queensland)**
20	**CALLITRIS WOODLAND, HEATHLAND**
21	**Low woodlands and low open-woodlands of *Melaleuca* spp. predominantly on depositional plains in the tropical north**
22	**ACACIA DOMINATED FOREST, WOODLAND AND SHRUBLAND**
23	***Acacia spp.* on residuals. Species include *A. stowardii, A. shirleyi, A. microsperma, A. catenulata, Acacia rhodoxylon***
24	***Acacia aneura* dominated associations on red earth plains, sandplains or residuals.**
25	***Acacia cambagei/A. georginae/A. argyrodendron* dominated associations (includes wooded downs - *A. tephrina,* mixed species)**

Raster layers of rainfall in the wettest quarter (Jeffrey 2001) and temperature in the wettest quarter (Jeffrey 2001) were reclassified into 50mm classes and 0.5^{o}C classes respectively. These were then converted to shapefiles and clipped with the study area/vegetation masks. Areas of rainfall and temperature groups in the study area were calculated.

Basal area

Basal area (at 130 cm) was derived from a raster layer of 0.001 degree resolution estimated from satellite imagery (Department of Natural Resources, Mines and Energy (Queensland) 2001). This was reclassified into classes of 2m^2/ha basal area and clipped with the study area/vegetation masks (Leica Geosystems GIS and Mapping, 2003). The layer was analysed as a raster due to its fine resolution.

Area of BA classes were derived by counting the number of pixels per BA class, then multiplying by the area of a pixel.

TRAPS site attributes

TRAPs site locations were overlaid on each attribute layer to obtain a value for each site (spatial join). The BVG for each site was taken to be the BVG that sampling operators identified at the actual site rather than what was indicated on the map. BVGs for new sites were taken from the data layer which was assumed to be correct.

Basal area for each TRAPS site was calculated by taking the last recorded basal area (30cm) and dividing by a correction factor of 1.5294, to convert to basal area at breast height (130cm).

9.1.4 Representativeness testing using Chi square analysis

To check the representativeness of the TRAPS sites against the study area, the percentage number of TRAPs sites containing each variable was graphed against the percentage area of each variable in the study area (eg 9 % of TRAPs sites are in the 250mm rainfall group compared to 12% of the study area in the 250mm rainfall group) (figure 3a and 3b). A chi square analysis was then carried out (Table 2) which tests similarity between the TRAPS site classes and the corresponding study area classes.

Attribute classes that contributed most to the chi square statistic were identified and used as the basis to select the new TRAPs sites. The number of classes selected varied with the attribute and ranged from three soil groups to seven temperature groups. BVG 18b (open woodlands on duplex soils with *Euclyptus populnea* and *E. melanophloia* dominant vegetation) has been over represented in this analysis due to being a focus of interest for the original TRAPS network.

No basal area groups were selected, as no single group had any great contribution to the chi square statistic.

The BVG distribution was used to calculate the number of additional sites needed to increase their representativeness compared to the study area. This resulted in 17 extra sites.

9.1.5 Selection of 17 sites

The under represented attribute classes were selected from their respective layers and exported to shapefiles. There were four BVGs selected in the vegetation attribute. To maximise correction of representativeness, each BVG was overlaid with the selected rainfall, temperature and soil groups to identify areas that satisfied all the attributes. Polygon areas were calculated.

For each of the four selected BVGs, all possible combinations of the selected attributes were assessed and the areas calculated. The combinations were ranked by area. The highest ranks were selected with each combination comprising the attributes for one site. Two sites for open eucalypt woodland (BVG =17) and high rainfall (>850 mm) were added to the selection, as these did not have a high area ranking but are regarded as lacking in the TRAPs network. This gave a total of 17 new sites (figure 4).

A site was picked within each of these envelopes using a random point generator (Beyer 2004). Sites that were within 20 km of another site were deleted and another point generated. One site was generated in an obviously inaccessible area (Shoalwater Bay military area), therefore another point was generated.

9.1.6 Checking representativeness

To test their ability to satisfy representativeness, the 17 new sites were added to the existing sites and the Chi square analysis repeated. The probabilities obtained were within acceptable limits (table 2).

Table 2. Probabilities obtained from the Chi square analysis on the ‘original TRAPS sites’, the ‘original + 17 sites’ and ‘original + 17 + grid sites’.

	Probability level				
	vegetation	soil	rainfall	temperature	basal area
original TRAPS sites	0.009	0.003	0.08	0.089	0.475

original + 17 sites	0.363	0.44	0.957	0.74	0.844
original + 17 + grid sites	0.849	0.852	0.447	1	0.982

9.1.7 Ideal woodland monitoring network (grid sites)

The 17 new sites are a minimum solution to improve TRAPS site representativeness. There still remains many spatial gaps in the study area without sites, therefore a second set of sites was generated (grid sites).

A buffer of 50 km radius was generated around existing and the 17 new TRAPS sites. A 100 km grid, snapped to the Albers coordinate system, (Beyer 2004) was generated over the study area. Points were generated over intersecting grid lines (Beyer 2004). There were 55 points falling in areas not covered by buffer circles (figure 5). These were deemed to be grid site locations.

Each point was examined to ensure that it was located at least 500m from a non remnant vegetation area boundary and soil type could be determined from the soil layer. Points that did not satisfy these conditions or lay in a non remnant area or non mask area were moved to the closest suitable position.

The points were overlayed with the vegetation, temperature, rainfall and soil layers to collect these attributes. These points were combined with the 17 previous points and original TRAPS sites and a Chi square analysis was performed (figure 6a and 6b). The probabilities were greater than those of the 17 sites and existing TRAPS, except for rainfall (table 1).

This grid system could be extended to other areas of Queensland outside the study area.

9.1.8 Limitations and uncertainties of the methods

Accuracy of results depends on the reliability of data used in the analysis. This can be affected by positional and attribute reliability. Also differences between the definition of remnant vegetation may affect results. Remnant vegetation for the BVG map was defined as vegetation where at least 50% of the cover and more than 70% of the height of the original stratum remains. On the vegetation map layer, 30 TRAPS sites lay in non remnant vegetation areas. Whereas 12 of these TRAPS sites were actually classed as remnant vegetation by the TRAPS project personnel. Five of these were within the vegetation layer positional attribute margin of error of 100m.

The study area encompasses 99 016 104 ha. Non remnant areas, grasslands and non classified areas account for 27 914 678, 13 540 422 and 4 491 367 ha respectively. There is potential for discrepancies in classification to lead to minor differences in areas.

4 491 367 ha of the study area was not mapped in the vegetation layer and therefore not included in the analysis (figure 7). These areas coincide with areas lacking existing TRAPS sites. Grid sites falling in these areas were relocated to mapped areas.

The areas mentioned above also occur on the soils layer as the same data sets were probably used in the construction of the soils map. The soils layer also had large areas (7 913 734 ha) that had no classification. These areas were not included in the analysis. The areas tended to occur in blocks (figure 7) and these areas were not used for site selection.

We are unable to assess the accuracy of soil types at each TRAPS site derived from the map as we do not have Australian Soil Classifications (ASC) for the TRAPS sites. The soil map was derived through interpolation of a network of point data (Brough 2001).

The grid network of sites resulted in many sites in unsuitable areas. This was due to sites landing in non remnant vegetation areas, landing outside the study area mask or being situated less than 500m from a cleared area boundary. 34 sites were moved an average distance of 7 km. This figure is skewed by six sites, including three sites located in areas with no vegetation/soil classification (moved 50, 30 and 64 km), one site in rainforest vegetation (moved 34 km) and two in grassland (moved 25 and 30km). If these six sites are removed from the calculation, the average distance moved was 3.1km.

The addition of the grid TRAPS sites resulted in higher Chi square probabilities for all attributes except the rainfall. This was due to sites initially falling in grassland areas (grasslands were removed from the analysis). These areas coincide with the 200 to 250mm wettest quater rainfall group and resulted in a spike of 15 TRAPS sites in that rainfall group. Though the Chi square probability is lower, it is still acceptable. The probabilities for temperature and soil were not affected as much, as these attributes were not as highly correlated with grassland vegetation. Sites falling in grassland were moved to the closest suitable vegetation area, which was usually gidgee (BVG 25). It was proposed to leave these sites in the network as Gidgee is a vegetation group of interest and the original plus 17 extra sites are under represented for BVG 25.

9.1.8.1 Field logistics

This exercise assumed that the data layers are accurate for the newly selected sites and that these selected sites are accessible. However, when locating the sites this may not be the case, eg the BVGs may be different. Once a site position is located it will still be established, however the representativeness testing will require re-analysis at a later date.

9.1.8.2 Summary

The methods used in this study develop an improved TRAPS network that satisfies the greatest deficiencies in the existing TRAPS site attributes of broad vegetation group, soil type, rainfall, temperature and basal area. The biggest problem with the process was the vegetation and soils layers had large areas with no classification that had to be excluded from the analysis. Another problem will be the extent to which the mapped sites and their attributes agree with the actual.

Michael Yee and Steven Bray

9.1.9 References

Beyer, H. (2004). *Hawth's analysis tools.* (ArcView extension). Ver 3.04.
http://www.spatialecology.com/htools

Brough DM (2001). *Creation of Soil Attribute Surfaces for Landscape Salinity Hazard Assessment.* Enhanced Resource Assessment 2001–04. Queensland Department of Natural Resources and Mines, Brisbane.

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Jeffrey, S.J., Carter, J.O., Moodie, K.B. and Beswick, A.R. (2001) Using spatial interpolation to construct a comprehensive archive of Australian climate data. Environmental Modelling and Software 16/4: 309-330.

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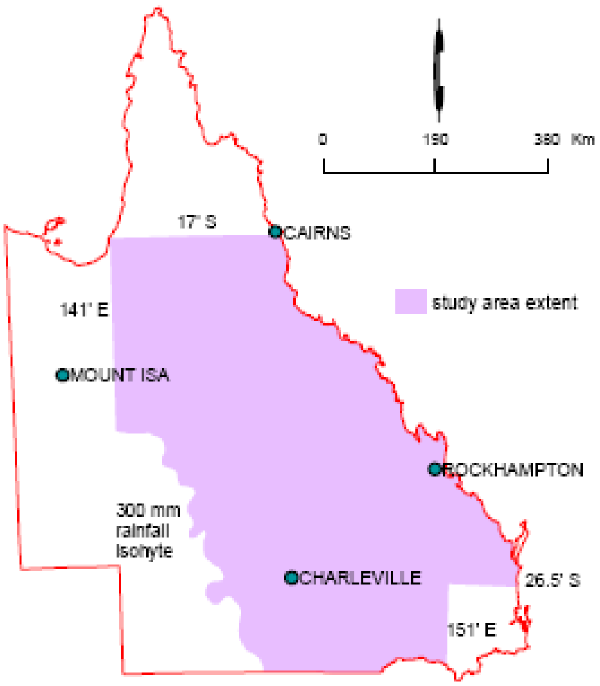

Figure 1 Map of the woodland study area targeted by the TRAPS woodland monitoring network.

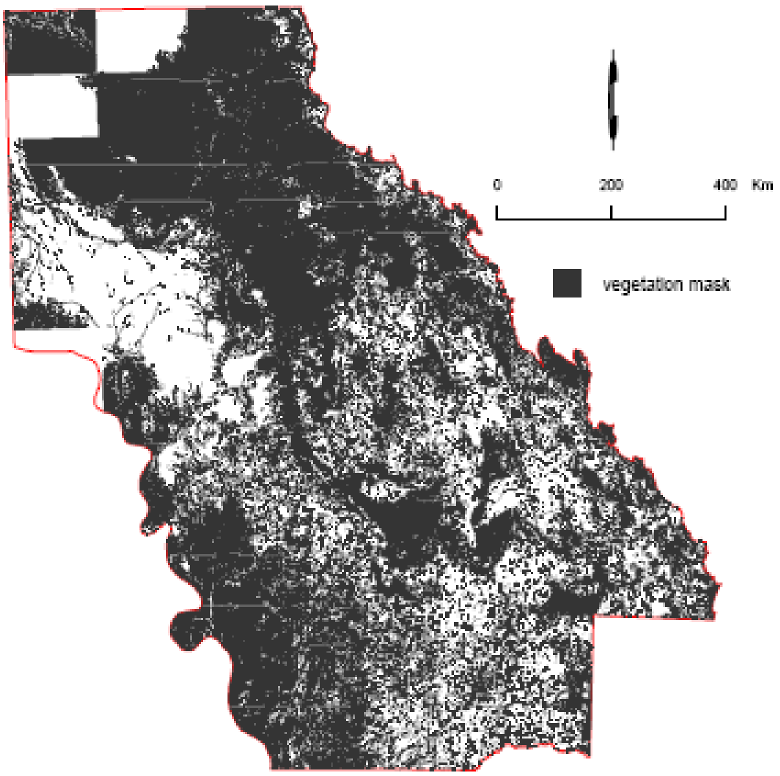

Figure 2 Vegetation mask used in GIS analysis

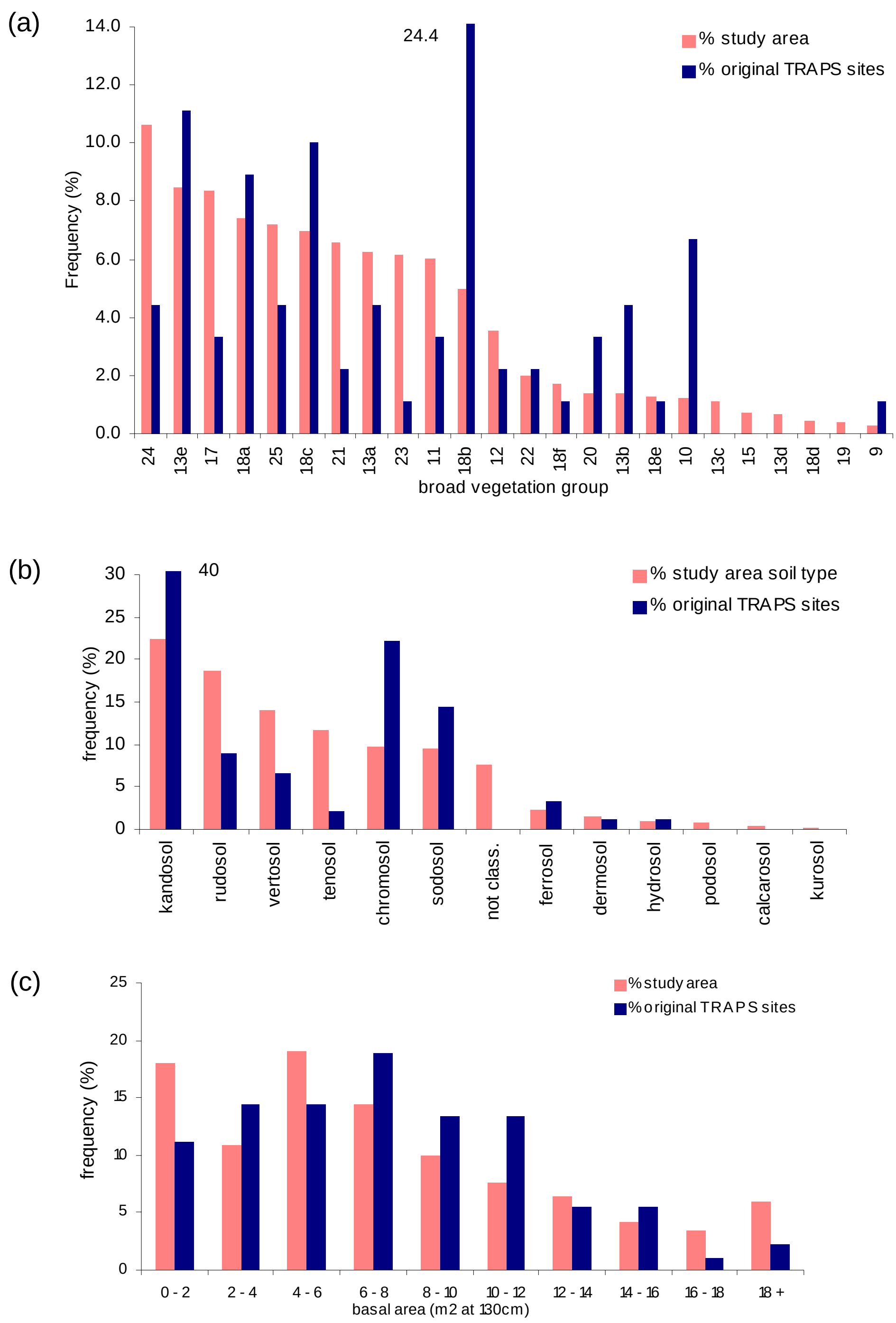

Figure 3a. The representativeness of the attributes broad vegetation group (a), soil type (b) and basal area (c) of the original TRAPS sites, against the proportion of the attributes in the study area.

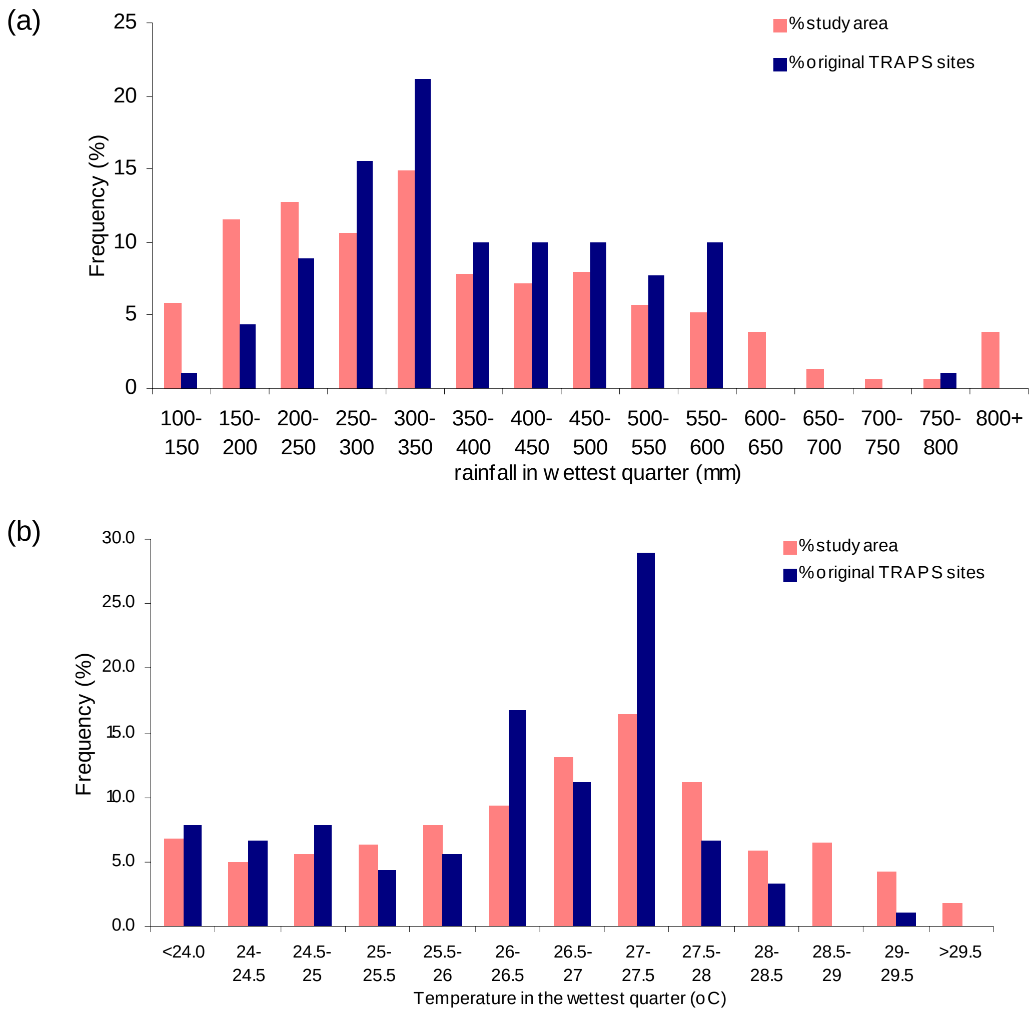

Figure 3b. The representativeness of the attributes rainfall in the wettest quarter (a) and temperature in the wettest quarter (b) of the original TRAPS sites, against the proportion of the attributes in the study area.

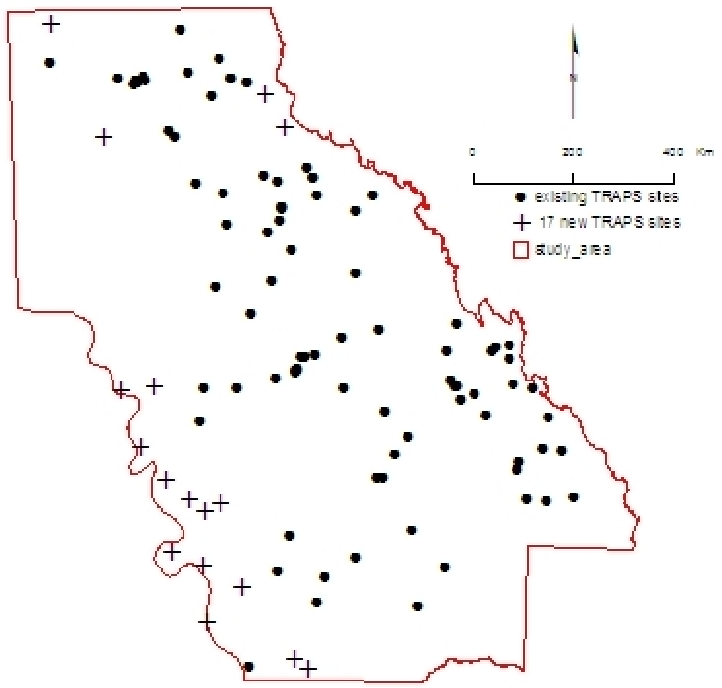

Figure 4 The study are showing the original TRAPS sites and the 17 new proposed sites.

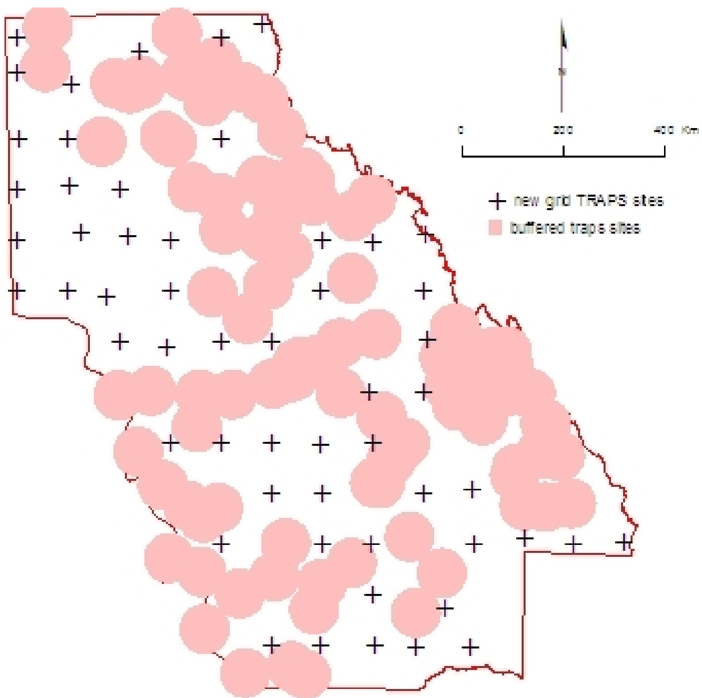

Figure 5 The original TRAPS sites and 17 proposed high priority sites with a 50km radius buffer (pink dots) and the 55 proposed grid sites.

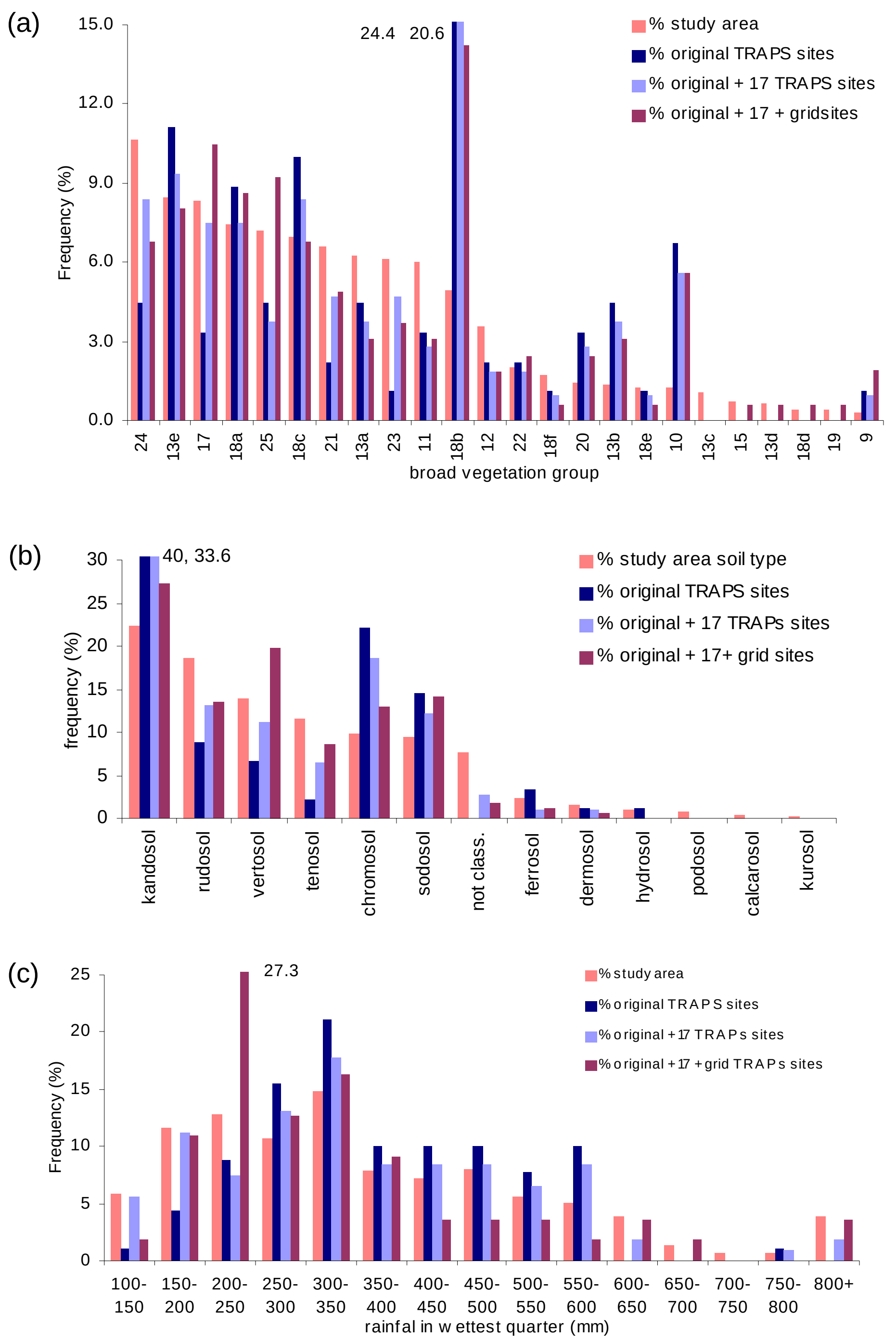

Figure 6a. The representativeness of the attributes broad vegetation group (a), soil type (b) and rainfall in the wettest quarter (c) of the original TRAPS, original +17 sites and original +17 +grid sites, against the proportion of the attributes in the study area.

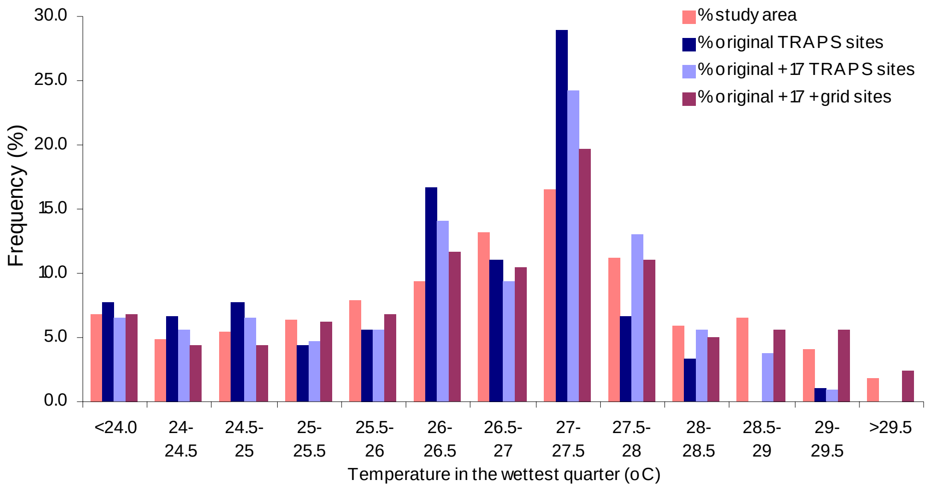

Figure 6b. The representativeness of the attributes temperature in the wettest quarter of the original TRAPS, original +17 sites and original +17 +grid sites, against the proportion of the attributes in the study area.

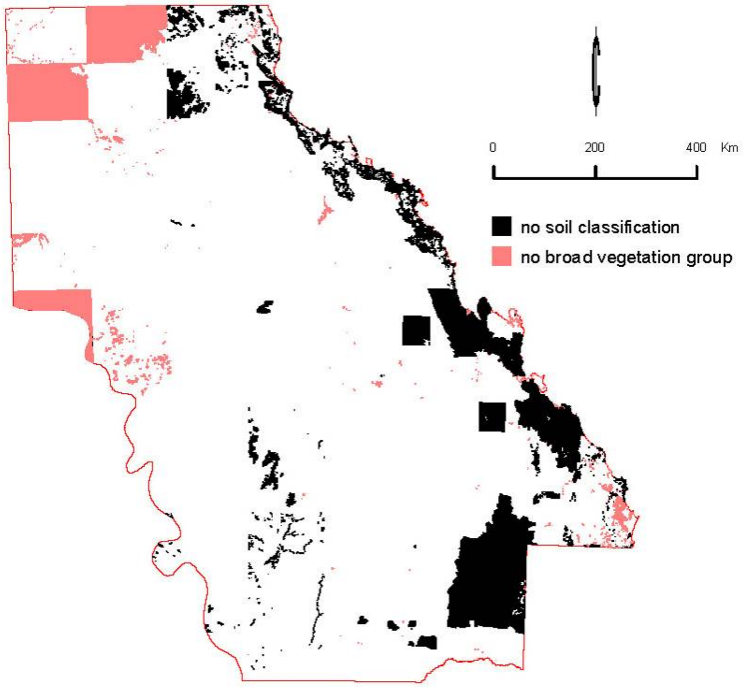

Figure 7 Areas with no soil or vegetation classification and therefore not used to generate study area statistics.

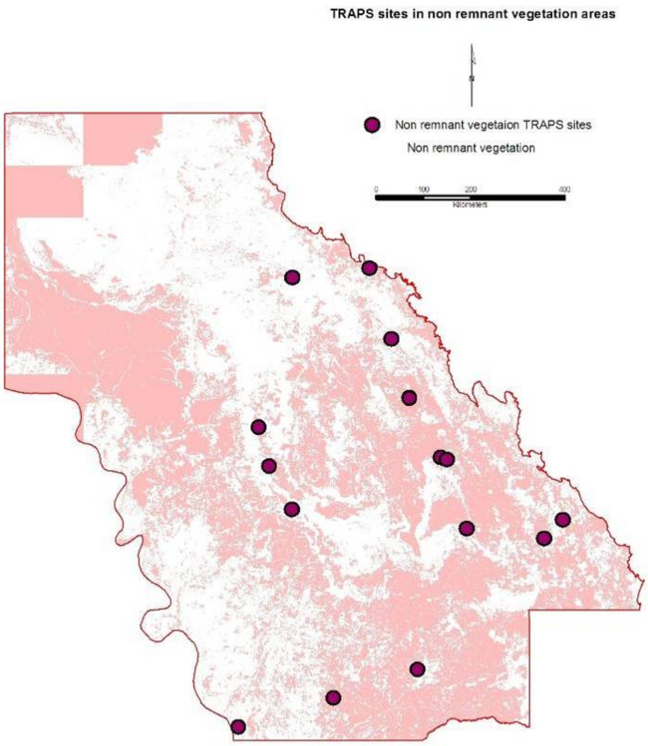

Figure 8 Non-remnant TRAPS sites

9.2 Appendix 2 Co-operator package example

Annual Co-operator's Information Package: "H Creek"

Project NBP.333: Understanding the Dynamics of Queensland's Grazed Woodlands

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Monitoring Site Population Dynamics

We have included for your information brief a description of the vegetation that we have recorded with the eucalypt monitoring site on 'H Creek'. The site is one of the original TRAPS monitoring sites having been established in 1983. It is providing us with important long-term data on woodland population dynamics.

This site is described as an open box woodland. At the last recording in 2003, the site basal area was 17.088 m^2/ha for about 610 plants/ha. The poplar box (*Eucalyptus populnea*) dominates the site, as they contribute to 89% of total site basal area, and 37% of total site numbers. Understorey species such as red ash (*Alphitonia excelsa*), acacia (*Acacia* spp.) and coffee bush (*Breynia oblongifolia*) contribute to 40% of total site numbers, but these species contribute very little in terms of site basal area.

During the monitoring period (1983-2003) total site basal area has increased, which is driven by the growth of eucalypt trees (Graph1 and Table 2).

Total plant numbers during the monitoring period have decreased significantly. This is from a reduction in coffee bush numbers. This decrease in numbers is evident in Table 3 and Graph 2, and is occurring in the shrub category. The pictorial series doesn't reflect these changes as the reduction of numbers was from the loss of small plants within the grass layer. Therefore, the site is maintaining an open structure, with no large increases in basal area or numbers, since monitoring began.

Future monitoring and analysis of the monitoring site data will highlight changes within species populations. These changes will include identifying seedling flushes, as well as investigating the development, or suppression, of these recruitment events. Other population changes within the stand structure of sites will also be detected with further analysis and monitoring. Information about the management of sites, such as fire frequencies, that may cause changes, or maintain systems, will require some input from site co-operators in the form of surveys and feedback forms.

Table 1 lists all of the plants found in the monitoring area marked by the steel posts. Tables 2 and 3 show the basal area and density for each species during the monitoring period. Graphs 1 and 2 show total site basal area and density changes for shrubs (less than 4m tall) and trees (greater than 4m tall) during the monitoring period.

Thank you for your co-operation and allowing us to continue maintaining this site.

Table 5. List of species names (scientific and common) found at monitoring site.

Species full	Species Common Name
Acacia leiocalyx	Black wattle
Acacia salicina	Sally wattle, Native willow, Cooba
*Acacia spp.**	Acacia species, wattles
Alphitonia excelsa	Red ash, Soap tree
Breynia oblongifolia	Coffee bush
Canthium species	Canthium
Cryptostegia grandiflora	Rubber vine
Cupaniopsis anacardioides	None listed
Diospyros ferrea	None listed
Eucalyptus crebra	Narrow leaved ironbark, Narrow leaved red ironbark
Eucalyptus hybrid	Hybrid Eucalypt
Corymbia papuana	Cabbage gum, Molloy white gum, White gum, Desert gum.
Eucalyptus platyphylla	Ringing gum, White gum, Poplar gum
Eucalyptus populnea	Poplar box, Bimble box
*Eucalyptus spp.**	Eucalyptus species
Corymbia tessellaris	Moreton Bay ash, Carbeen, Carbeen bloodwood
Myoporum acuminatum	Native myrtle, Boobialla, Pointed boobialla, Waterbush
*Opuntia spp.**	Prickly pear
Opuntia stricta	Spiny pest pear
Opuntia tomentosa	Velvety tree pear

*small seedlings that have been grazed or broken off, have been unidentified at the time of recording and are usually identified at subsequent recordings.

Table 2. Species basal area (m²/ha) at the monitoring site.

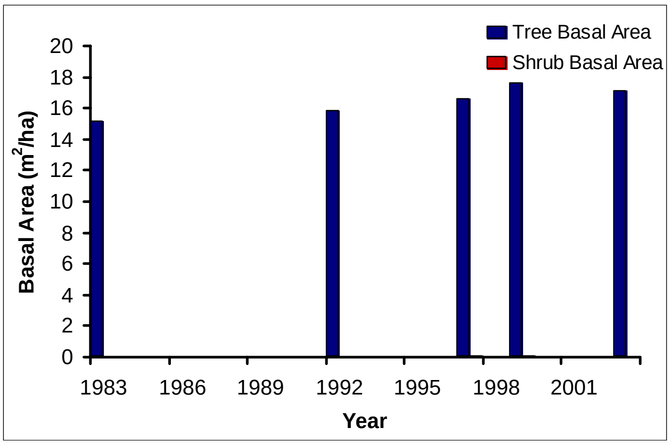
Species full	1983	1992	1997	1999	2003
Acacia leiocalyx	0	0			
Acacia salicina	0.002	<0.001	0.024	0.027	0.025
Acacia spp.		0			
Alphitonia excelsa	0	0	0	0	0
Breynia oblongifolia	0.002	<0.001	0	0	0
Canthium species	0	0			
Cryptostegia grandiflora	0				
Cupaniopsis anacardioides	0.007	0.020	0.036	0.050	0.064
Diospyros ferrea	0				
Eucalyptus crebra	1.215	1.323	1.197	1.305	1.278
Eucalyptus hybrid	0.505	0.527	0.513	0.550	0.541
Corymbia papuana	0.167	0	0	0.001	0.002
Eucalyptus platyphylla		0.084	0.079	0.096	
Eucalyptus populnea	13.102	13.886	14.809	15.670	15.179
Eucalyptus spp.	0	0	0	0	0
Corymbia tessellaris	0.218		0	0	0
Myoporum acuminatum	0	0.006	0.005	0	0
Opuntia spp.					0
Opuntia stricta			0	0	0
Opuntia tomentosa		0	0		
Total Basal Area	**15.218**	**15.846**	**16.663**	**17.699**	**17.088**

Table 3. Species numbers (plants/ha) at the monitoring site.

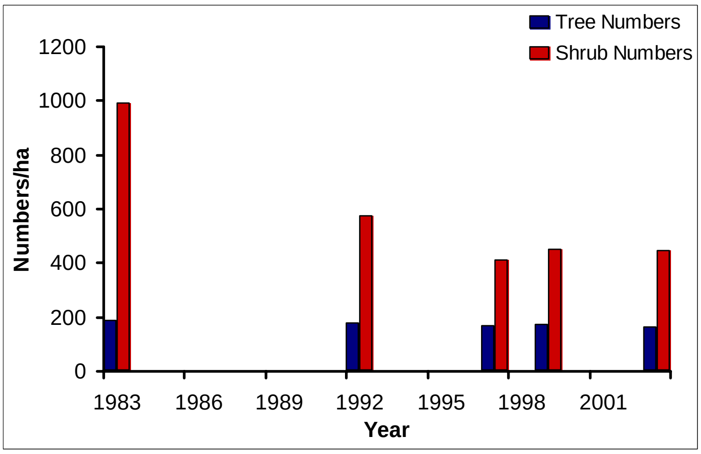
Species full	1983	1992	1997	1999	2003
Acacia leiocalyx	30	20			
Acacia salicina	30	45	65	55	65
Acacia spp.		10			
Alphitonia excelsa	85	80	80	85	65
Breynia oblongifolia	585	140	55	80	115
Canthium species	10	5			
Cryptostegia grandiflora	35				
Cupaniopsis anacardioides	5	5	5	5	5
Diospyros ferrea	5				
Eucalyptus crebra	15	15	10	10	10
Eucalyptus hybrid	10	10	20	20	20
Corymbia papuana	70	60	60	65	60
Eucalyptus platyphylla		5	5	5	

Species full	1983	1992	1997	1999	2003
Eucalyptus populnea	265	290	235	250	225
Eucalyptus spp.	25	35	15	5	5
Corymbia tessellaris	5		5	10	10
Myoporum acuminatum	5	25	15	15	10
Opuntia spp.					10
Opuntia stricta			5	20	10
Opuntia tomentosa		10	5		
Total Numbers	**1180**	**755**	**580**	**625**	**610**

Graph 1. Total basal area (m^2/ha) for shrubs and trees at the monitoring site.



Graph 2. Total site numbers (plants/ha) for shrubs and trees at the monitoring site.



'H Creek' Woodland Measurement Site