Review of Land Cover Monitoring in the Northern Territory

Department of Natural Resources, Environment, the Arts and Sport, Northern Territory, Australia

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Technical Report 11/2009D

CARING FOR OUR COUNTRY

Northern Territory Government

Australian Collaborative Land Use Mapping Programme

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EXECTUIVE SUMMARY

A national land cover monitoring program has been proposed. Workshops held in 2008 and 2009 to review the monitoring and modelling of erosion by wind and water recommended that:

- ground cover should be monitored through remotely sensing bare ground and fractional woody and non-woody cover.
- a network of permanent ground reference sites specifically designed for gathering remote sensing data on a mix of cropping and rangeland sites be established.

The proposed data collection methodology is based on the Queensland SLATS methods (Statewide Landcover and Trees Study; Danaher *et al.* 1996 and 1998; Scarth *et al.* 2006) with changes incorporated as necessary.

To prevent duplication and reduce costs, where practical, existing monitoring sites, such as for soil condition (including erosion risk), ground cover and cropping practice, should be utilised and adapted.

In this report, the methodologies of four NT land cover monitoring programs were compared and contrasted with the SLATS method. The programs are:

- Soil Condition Monitoring in the Daly Basin (agricultural lands)
- Fire Plot Monitoring (indigenous lands and national parks)
- Tier 1 (Pastoral Land Monitoring)
- SwiftSynd (Pastoral Land Monitoring)

No existing land cover monitoring program in the Northern Territory collects data that is compatible with the modified SLATS methodology.

Subject to the development of appropriate site selection criteria for proposed national land cover monitoring program, involvement of the NT would require:

a. New sites in the agricultural areas, and
b. Additional SLATS compatible data may be collected at selected Tier 1 monitoring sites; however, additional new sites may also be required.

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Acronyms and Abbreviations

Aussie GRASS	Australian Grassland and Rangeland Assessment by Spatial Simulation
ACLUMP	Australian Collaborative Land Use Mapping Programme
ACRIS	Australian Collaborative Rangeland Information System
BGI	Bare Ground Index
BRS	Bureau of Rural Science (within the Australian Government Department of Agriculture, Fisheries and Forestry)
Bushfires NT	Bushfires Council of the Northern Territory
CSIRO	Commonwealth Scientific Information and Research Organisation
DAFF	Department of Agriculture, Fisheries and Forestry
DBH	Diameter Breast Height
DEWHA	Department of the Environment, Water, Heritage and the Arts
DRDPIFR	Department of Regional Development, Primary Industry, Fisheries and Resources (formerly Department of Primary Industry, Fisheries and Mines - DPIFR)
FPC	Foliage Projective Cover
GCI	Ground Cover Index
GRASP	Grass Production Model
LAI	Leaf Area Index
LFA	Landscape Function Analysis
LUMIS	Land Use Management Information System
LUMP	Land Use Mapping Project
MODIS	Moderate Resolution Imaging Spectroradiometer
NAFI	Northern Australia Fire Information
NAILSMA	North Australia Indigenous Land and Sea Management Alliance
NCLUM	National Committee for Land Use and Management
NLWRA	National Land and Water Resources Audit (now disbanded)
NORFOR	Northern Forests Mapping
NRETAS	Department of Natural Resources, Environment, the Arts and Sport (NT)
NT	Northern Territory
PLB	Pastoral Land Board (NT)
SLATS	Statewide Landcover and Trees Study (Queensland)
TS-CRC	Tropical Savannas Management Cooperative Research Centre
TWG	Technical Working Group
WALFA	West Arnhem Land Fire Abatement Project

Definitions

Land cover

Land cover refers to the physical surface of the earth, including various combinations of vegetation types, soils, exposed rocks and water bodies as well as anthropogenic elements, such as agriculture and built environments. Land cover classes can usually be discriminated by characteristic patterns using remote sensing. (BRS 2006).

Rangelands

Those areas where the rainfall is too low or unreliable and the soils too poor to support regular cropping and includes the monsoonal north and the vast areas of semiarid and arid Australia (Bastin & ACRIS 2008:p1). According to this definition the landscape of the Northern Territory is rangeland.

Monitoring

The regular collection and analysis of information to assist timely decision making, ensure accountability and provide the basis for evaluation and learning. It is a continuing function that uses methodical collection of data to provide management and the main stakeholders of an ongoing project or program with early indications of progress and achievement of objectives. (DEWHA & DAFF 2009:p29).

Land System

Areas or groups of areas, which are characterised by recurring patterns of landforms, soils and vegetation (Lynch and Wilson1998:p1).

Fractional Cover

A remote sensing product in which each image cell (pixel) is assigned a set of values that reflect the relative influence of photosynthetic, non-photosynthetic and bare soil components (Guerschman *et al.* 2009)

Cropping

Dryland or irrigated farming where native vegetation has largely been replaced by introduced species though clearing and sowing of new species using tillage or planting. The crops may be perennial or annual and the land may be utilised in a rotation farming system (after BRS 2006)

Modified Pasture

Pasture and forage production, both annual and perennial, based on significant active modification or replacement of the initial vegetation (BRS 2006).

1. Introduction

1.1 Background

Land cover data is required and collected by many levels of government and regional bodies for a range of issues, from monitoring and assessing land, soil and vegetation condition, to monitoring greenhouse emissions and water resource modelling (NLWRA 2007). The capacity to monitor the impact of land management practices was important at all levels from national to regional and measurement of ground cover is generally a good indicator of land management and becomes increasingly useful when a time series is available (NLWRA 2007).

Ideally a land cover data set should be generated once and be available to all as well as work up and down scales (NLWRA 2007). Workshops held in 2008 and 2009 to review the monitoring and modelling of erosion by wind and water support the work by Leys *et al* (2009) which recommends that *Ground cover should be monitored through remotely sensing bare ground and fractional woody and non-woody cover….. Three products were selected:*

> *1. Bare ground index (BGI).*
> *2. Fractional non-woody cover (discriminating the photosynthetically-active vegetation (PV), the non-photosynthetically-active vegetation (NPV) and bare ground (BG)).*
> *3. Fractional woody cover (FWC, proportion of photosynthetically-active vegetation contributing to the overstorey).*

Leys *et al* (2009) recommend that observational methods should be based on a network of permanent ground reference sites specifically designed for gathering remote sensing data on a mix of cropping and rangeland sites. These ground reference sites would be used to calibrate high resolution satellite imagery, which would then be used to calibrate medium scale satellite imagery and so on. The data would have quality assurance and error estimation and enable mapping of spatial and temporal scales with the methodology based on the Queensland SLATS methods (Statewide Landcover and Trees Study; Danaher *et al.* 1996 and 1998; Scarth *et al.* 2006) with changes incorporated as necessary.

The Australian Collaborative Land Use and Management Program (ACLUMP) utilises land cover data to map land use and is developing the capacity to spatially locate and map land management practices, and thus has a requirement for consistent land cover data across Australia.

ACLUMP has sought support from the State Agency members of National Committee for Land Use and Management (NCLUM) to establish a network of ground cover reference sites. These sites would be used to calibrate and test ground cover data in cropping and modified pasture land uses derived from satellite imagery. Data collection would be standardised using recommendations of a technical working group (TWG). To prevent duplication

and reduce costs, where practical, existing monitoring sites, such as for soil condition (including erosion risk), ground cover and cropping practice, should be utilised and adapted.

1.2 Objectives

ACLUMP proposes to establish national protocols for producing a data set of ground cover maintenance. This data set will focus on critical levels of ground cover (the bare to low levels including both photosynthetically and non-photosynthetically active vegetation) under *cropping* and *modified pasture* land uses. A national network of reference sites will be used to calibrate and validate the ground cover levels estimated and to support the interpretation of likely land management practices from satellite imagery.

With the assistance of funding under Caring for our Country, ACLUMP will collate information on *existing monitoring sites* to:

I. Assess their suitability as ground cover reference sites for calibration and validation of remote sensing products
II. Compare different methods used to collate information on ground cover (i.e. within the rangelands) and/or land management practices (i.e. for erosion risk) to assist in determining national standards
III. Produce a spatial data set showing their location, size, land use, purpose, and attributes collected.

This data set will be used to assess the suitability of existing monitoring sites for calibrating and validating remote sensing products of ground cover levels and the associated land management practices. From this assessment, a national network of reference sites will be proposed and costed for on-going monitoring of ground cover within cropping and improved pasture grazing systems.

2. Land Use

The majority of land in the Northern Territory is managed either for pastoralism or indigenous use, covering 44% and 39% respectively (Berghout *et al.* 2008). National parks and other conserved/ minimal use areas comprise 16%. Comparatively, together dry land and irrigated agriculture and horticulture comprise less than 0.2% and are confined mostly to the monsoonal Top End with a small but economically significant area of irrigated horticulture near Ti Tree in central Australia. "*Striking the Balance*" (O'Gara 1998) provides a concise introduction to agriculture and agricultural practices in the Top End. A revised edition of this book will likely be released in 2009 (O'Gara, *pers comm.* 2009).

3. Monitoring Programs

3.1 Data Collection for Proposed National Land Cover Monitoring Program

The ACLUMP Land Management Practices (LMP) TWG supports the recommendations by Leys *et al* (2009) that data collection for the proposed national monitoring program should facilitate quantitative estimation of fractional cover of photosynthetic vegetation, non-photosynthetic vegetation and bare soil as proposed by Guerschman *et al.* (2009). The collected data should also enable quantitative estimation of foliage projective cover (FPC), ground cover (GCI) and bare ground (BGI) indices, some or all of which are used by current land cover monitoring programs to assess landscape condition (e.g. Scarth *et al.* 2006; Karfs *et al.* 2001).

The proposed data collection methodology is based on the Queensland SLATS methods (Statewide Landcover and Trees Study; Danaher *et al.* 1996 and 1998; Scarth *et al.* 2006) with changes incorporated as necessary. Data collected by NT monitoring programs are compared and contrasted with the SLATS method.

Overview of the data collection for the SLATS method

The SLATS method is outlined below after Scarth *et al.* (2006). An example field SLATS field data sheet is included as Appendix 1.

Field data acquisition
At each field site a range of measurements are taken:

- *Collection of discrete point transect sampling data to determine ground cover and the Foliage Projective Cover (FPC) of the overstorey and midstorey woody vegetation;*
- *Description of general site details, including characteristics such as soil and rock hue value and chroma, tree basal area, dominant species, and soil surface characteristics according to the method described by Tongway and Hindley (1995).*

Transect sampling
The original SLATS methodology utilised two 100 m perpendicular transects. This has since been modified to incorporate up to 3x100 m transects, the midpoint of each (i.e. 50 m mark) centred on a common point. The following is taken from Scarth *et al.* (2006). *A modified discrete point sampling method is used such that at every metre interval a recording is made of the ground cover, midstorey and overstorey (Brady et al., 1995). The discrete point sampling technique was employed because it provided the best compromise between repeatability between different operators without requiring estimation training and regular calibration, and the time taken to measure each site in the field.*

General site description

- *Soil hue, value and chroma measurements. These data are collected for both wet and dry soil and for different soil surface conditions, e.g. soil crust, disturbed soil, windblown surface deposits (sand);*
- *Rock hue, value and chroma;*
- *Tree basal area at 7 points (original method proposed in Scarth et al. (2006) used 5 points) using calibrated optical wedges;*
- *Dominant species by biomass within ground/ midstorey / overstorey layers;*
- *Soil surface characteristics, such as erosion features, soil microtopography, surface nature, faunal activity; and*
- *Evidence of recent site disturbance, e.g. fire, clearing, etc.*

And cover recordings:

- *Bare soil*
- *Rock*
- *Green attached leaf*
- *Dead attached leaf*
- *Litter (including all organic litter, tree, grass, dung etc)*
- *Cryptogam (photosynthetic soil crust)*
- *Midstorey (woody material 0-2m) recordings of green leaf, dead leaf or branch; and*
- *Overstorey (woody material > 2m) recordings of green leaf, dead leaf or branch.*

3.2 Monitoring Programs in the Northern Territory

This section summarises monitoring programs in the NT that capture land cover data regularly using a consistent methodology and which are applied over a large geographic area. Programs of potential relevance to the proposed national land cover monitoring program are described in greater detail in the following sections.

Soil condition monitoring

Monitoring of land cover on cropping land and modified pastures is limited to a small soil condition monitoring trial project in the Daly basin focused on monitoring soil erosion by water that was established in 2007 using funding from the NLWRA (Berghout, unpub.). See Section 3.3 of this report for greater detail.

Monitoring the effects of fire

Bushfires NT and its collaborators collect data to assess the impact of fire on the environment in the absence of significant other land use, with this research being conducted primarily on Aboriginal land including joint managed national parks (Cooke 2000; Russell-Smith *et al.* 2000). See Section 3.4 for greater detail.

Pastoral land monitoring

Tier 1 and Tier 2 monitoring, designed as a tool for assessment and understanding of pastoral land management practices and their effects on the landscape, covers the extensive grazed pastoral lands and provides information to the NT Pastoral Lands Board and land managers (Karfs *et al.* 2001).

A second, more limited rangelands monitoring program, SwiftSynd, collects data on grazing lands across the NT for use within the AussieGrass model to forecast pasture growth and grazing utilisation (Dyer, Café and Craig 2001). Data from the SwiftSynd project is collected from fenced enclosures (Dyer, Café and Craig 2001), protected from grazing, and as such does not reflect the land cover of the surrounding grazed lands.

These programs are outlined in greater detail in Sections 3.5 and 3.6.

Modelling of land cover

In 2004, the CSIRO conducted a detailed review of all natural resource models used in the rangelands (CSIRO 2004). Only two related "land cover" type models, Aussie GRASS and GRASP, were described as having widespread usage including the Northern Territory. The SwiftSynd project provides the data for these models. Output from these models is used to predict understorey biomass and provides the capacity to monitor and forecast pasture growth (Dyer, Café and Craig 2001).

Biodiversity monitoring

A report on the *Status of Biodiversity Monitoring in the Rangelands* found that there is no widespread systematic biodiversity monitoring programme within in the NT (Day 2007). This report identified a number of current monitoring programs in the NT, many of which are small and *ad hoc*. A review of biodiversity monitoring in the NT by Griffiths *et al*. (2007) identified a range of small, targeted biodiversity monitoring programs occurring in the NT, but similarly observed that there was no systematic monitoring of biodiversity across the NT.

Other programs

A number of groups within agencies collect data as part of survey and mapping programs that may also provide validation for a national land cover dataset (see Appendix 5).

3.3 Soil Condition Monitoring

Overview

In 2006, the NLWRA commissioned a series of soil condition monitoring trials around Australia to test monitoring methodologies that were practical, repeatable and useful in reporting on soil condition, with particular reference to soil erosion at different scales (Dixon 2007). Each trial targeted one of four

condition indices: soil acidification, wind erosion, water erosion and organic carbon. The NT trial occurred in the Daly Basin and focused on soil erosion by water. As part of this trial, twelve sites were established on a mix of soil types and land uses in the Douglas River Catchment within the NT Daly Basin (Berghout, unpub.).

Previous studies in the Douglas-Daly area had shown that the major influences on sediment movement by rain splash and overland flow were the type and amount of vegetation cover, and changes to soil surface characteristics by management practices (NRETA 2007). These studies had established a relationship between sediment loss and attached ground cover (NRETA 2007). The cover threshold where runoff begins to dislodge sediment is approximately 40% (Dilshad *et al.* 1994), with vegetation cover in October, the start of the wet season, having the most direct bearing on the vulnerability of sites to erosion by water during the wet season (Berghout unpub.).

Site summary (after Berghout unpub.)

- Soil type. Two soil types were targeted: Kandosols (9 sites) and Hydrosols (3 sites). These soils are particularly targeted for agriculture and together make up approximately 45% of the Daly Basin.
- Land cover: cleared (7 sites), uncleared (5 sites)
- Land use type: cropping (3 sites), improved pasture (3 sites), grazing native vegetation (5 sites) and conservation (1 site).

At each site,

- 50 m x 50 m quadrat established on a homogeneous area
- Description of soil, vegetation and topographic position (as per McDonald *et al*. 1998),
- Slope determined using a dumpy level and transects aligned down slope.
- Geographic location of the upslope end of each transect recorded from GPS
- Compass bearing taken at beginning of transect.
- Recent land management practices recorded at each site reassessment
- Photo taken along each transect at commencement of each reassessment.

The NT trial incorporated two measures at each site: ground cover and landscape function analysis (LFA) (from NRETA 2007: Appendix B).

- Ground cover included measurement of foliage projective cover (FPC) using the line-intercept method described in Brocklehurst *et al*. (2007), Kunell *et al*. (1998). Ground cover assessment included a record of Attached Cover (AC) (= perennial and annual plants), detached cover (DC) (= organic litter), gravel and bare earth.

- Soil surface assessment – LFA methodology along a 100 m transect. Refer to Landscape Function Analysis: Procedures for Monitoring and Assessing landscapes. (Tongway & Hindley 2004). Observations are

made in the down slope direction. LFA proformas are available from http://www.cse.csiro.au/research/efa/lfa_summary.htm

Program Intent
Monitor soil condition at specific sites with respect to currently active and potential risk of erosion by water. There is no remote sensing component to this program.

Data Storage
Excel spreadsheet, field sheets and digital photographs.

Extent
Douglas River Catchment within the Daly Basin, NT.

Number of sites
12 sites established June – July 2007.

Current monitoring
Ground cover assessment is undertaken using the Point-quadrat vegetation cover method (after Berghout unpub.) See Appendix 2 for example field data sheet.

- *Parallel, evenly-spaced 50 m transects are walked up and down slope within the 50 x 50 m quadrat.*
- *Ground cover is recorded at points spaced at 1 m intervals. Cover at each point is recorded as 'attached', 'detached', 'litter', 'gravel' or 'bare ground'.*
- *Initially 100 points were recorded at each site (2 x 50 m transects), but this has been expanded to 400 points per site (8 x 50 m transects).*

Data collection measuring FPC and LFA was discontinued in 2008.

Site reassessment schedule
- Not systematic
- Includes early and late Dry Season.
- Several reassessments during the Wet Season (depending on seasonal conditions). Wet season conditions restrict access to some sites.

Comparison with SLATS
- Fixed sites
- Most sites within 100 m of land use boundary (e.g. sites on ploughed lands not greater than 100 m from non-ploughed land)
- Consistent width and separation of transects.
- Transects parallel, not in "star" pattern, and oriented perpendicular to slope of land.
- Basal data is not collected for woody plants / trees

- Limited surface data is collected e.g. micro-relief, cryptogam presence etc
- All covers based on estimation which is affected by experience of data collector. SLATS uses point intercept method to minimise operator influence on data. Consider undertaking SLATS style assessment at sites to provide quantifiable comparison of results.
- Insufficient data to accurately and repeatedly quantify FPC.
- Data does not separate photosynthetic and non-photosynthetic material.

Potential use within proposed national land cover program
As data currently collected is not compatible with the SLATS methodology, it is not suitable as input data for land cover / fractional cover classification for agricultural land.

Data has limited potential for validating MODIS derived fractional cover and FPC products.

Further investigation of the relationship between the modified SLATS style assessment and current soil condition monitoring land cover data collection is required. It is proposed to trial both methods on a selection of soil condition monitoring sites in 2009.

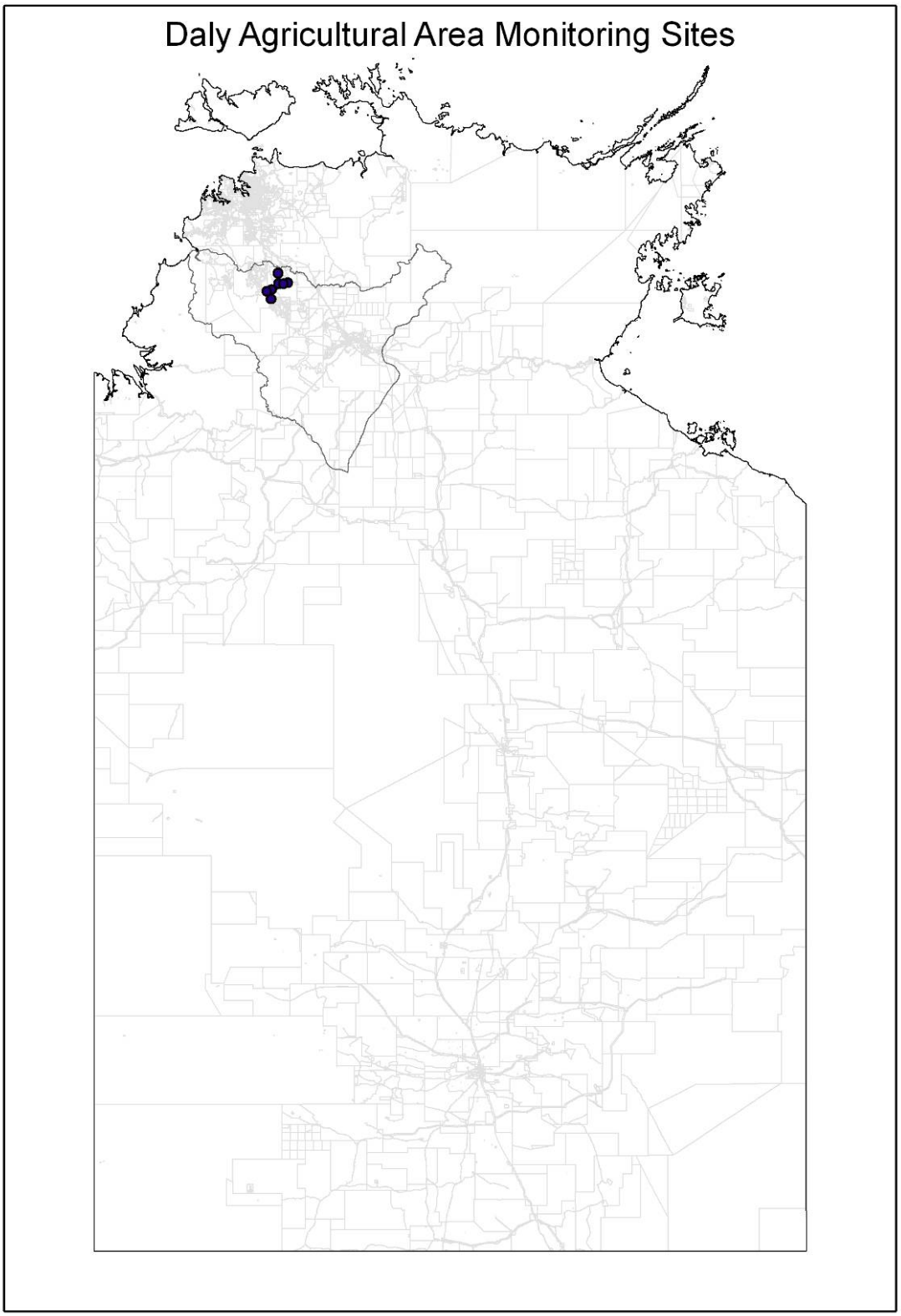

Figure 1 Location of Douglas - Daly Soil Condition monitoring sites

3.4 Monitoring the Effects of Fire

Overview
Monitoring and research into the effects of fire in the landscape of the Northern Territory has been conducted since the 1970s, with plot based experiments running from1973 to 1996 (Williams *et al.* 2003). Whilst predominantly carried out on Aboriginal land and national parks (Yates, *pers comm*.; Andersen *et al.* 1998; Cooke 2000; Russell-Smith *et al.* 2000), some work has also been carried out in relation to the use and effects of fire in pastoral lands (Dyer 2000). Currently, land managers in northern Australia are supported through the Northern Australia Fire Information website (NAFI) which displays close to real time location of active fires (also called "hotspots") and other information such as fire scars, fire history, fire weather etc (Tropical Savannas CRC, 2009). Numerous journal articles (particularly in the CSIRO published International Journal of Wildland Fire) and some texts have been written on the assessment and impact of fires in the NT.

Program Intent
Regional monitoring of fuel loads and effects of burning on vegetation communities using Landsat.

Data Storage
Excel spreadsheet, field sheets and digital photographs.

Extent
Mainly Aboriginal land and national parks in Top End and Gulf

Number of sites
In excess of 350 – no total figure provided

Current monitoring
The following is a summary of a meeting with Cameron Yates (Bushfires NT - NRETAS) held in June 2009 and with reference to Appendix 2 which contains the current vegetation and fuels sampling methodology.

Since 1998, the Bushfires NT monitoring program has been broadened with the primary driver of the current program being assessment of fire fuel load and effect on species/ vegetation community. Bushfires NT utilises 11 structural classes, with the number of sites proportional to the area of each class. Sampling is event driven with sites sampled to assess pre-fire fuel, then burnt, then assessed again for post fire fuel loads. Site re-visits are not systematic but opportunistic with sampling occurring at different times throughout the year. Sampling is not generally undertaken when the site has been affected by a non-planned fire, with both planned and unplanned burnt sites generally not visited for at least 2 years post burn. Data is utilised with Landsat imagery for regional assessments of fuel loads and effects of fire on vegetation communities.

Data collection is based on sets of three 100 m transects and focussed on quantification of ground fuel such as grass, litter, branches and large stems. The width of the transect is determined by the density of trees, with transects in forested sites being as narrow as 10 m whilst they may be up to 50 m wide when trees are widely spaced. Some ecological data is collected, including the names and estimated % cover of the dominant species in the ground, shrub and tree layers, as well as estimated % cover of rock and/or bare ground. Coarse estimates of tree canopy cover are collected at 5 m intervals along each transect using 3 values of 0 or no cover, <50% cover and >50% cover. Though not floristically comprehensive, site species composition data does enable assessment of changes in composition of dominant species over time. Changes in vegetation communities are predominantly driven by the frequency of late dry season fires..

According to Peter Brocklehurst (pers comm. 2009), in July 2009 the NAILSMA Carbon Abatement Initiative scientific research and field training program, and as part of Western Arnhemland Fire Abatement (WALFA) project, will be assessing, amongst many other scientific projects, the use of hemispherical photography for Leaf Area Index (LAI) estimation. Briefly, the objective is to determine the relationship between remotely sensed estimates of, LAI and those measured on the ground, for vegetation communities across the sandstone woodlands. Hemispherical photos (upward and downward) will be taken at a set height above ground every five metres along transects. On return from the field trip, data will be processed to generate an estimate of magnitude and variability of LAI. FPC data collection will occur at transects established for the fire abatement project. In addition, FPC estimates and basal sweeps will be undertaken as per the original NORFOR mapping along the same transects. The NORFOR methodology (Meakin *et al* 2001) is a somewhat similar approach but different configuration to the proposed *Land cover SLATS new method* as outlined in this technical paper. This will enable us to compare and evaluate the accuracy of the different methods as well as the utility of the current fire abatement transects for land cover estimates (perhaps MODIS rather than LANDSAT). Results will be published in scientific journals and/or technical reports. The outcomes of this project should be a useful adjunct to the proposed national Land Cover Monitoring project for the more wooded northern regions of the NT.

Site Reassessment schedule

- Not systematic.
- Each site assessed after at least 2 years post planned or unplanned burn. Some historical sites are assessed on a 5-yearly basis.

Comparison with SLATS methodology

- Width and separation of transects is not consistent, therefore sites are not of similar size, i.e. transect width varies depending on tree density. Sampling intensity per unit area is therefore not consistent particularly with respect to trees.
- Transects parallel, not in “star” pattern, and oriented randomly, i.e. usually perpendicular to the nearest road

- Basal data is collected for up to 20 trees >5 cm dbh per transect, however no plotless basal counts using a prism / basal wedge are collected.
- Limited surface data is collected e.g. micro-relief, cryptogam colour etc
- All covers based on estimation which is affected by experience of data collector. SLATS uses point intercept method to minimise operator influence on data.
- Insufficient data to accurately and repeatedly quantify FPC
- Insufficient data to quantify photosynthetic and non-photosynthetic material.

Potential use within proposed national land cover program
As data currently collected is not compatible with the SLATS methodology, it is not suitable as input data for land cover / fractional cover classification.

Current and historical data has limited potential for validating MODIS derived fractional cover and FPC products.

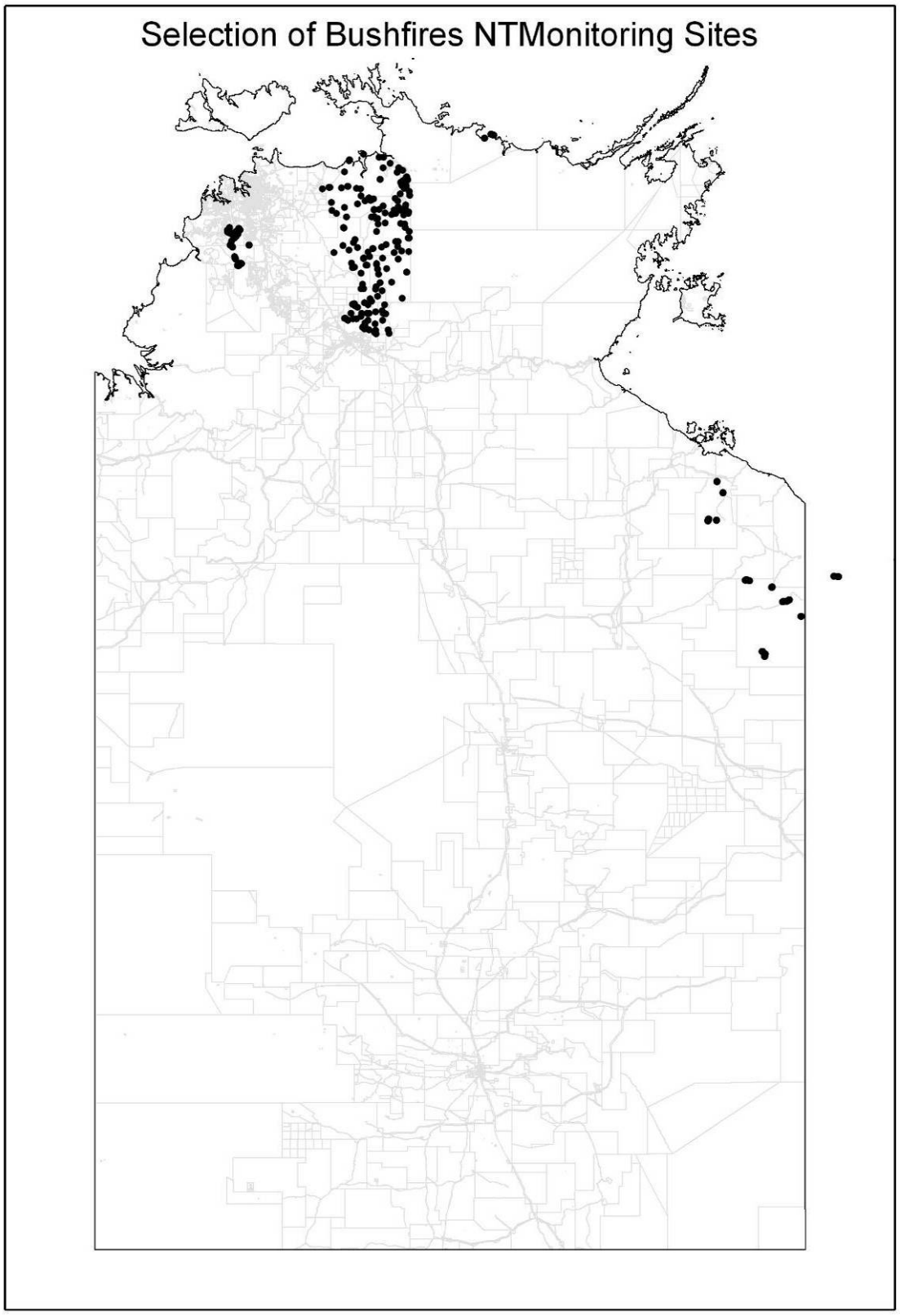

Figure 2 Location of selected Bushfires NT monitoring sites

3.5 Pastoral Land Monitoring – Tier 1 and Tier 2

Overview
Commencing in 1993, the pastoral land monitoring program was established to meet the needs of the Pastoral Land Board (PLB) (Karfs *et al.* 2001). The Board is required to monitor pastoral land management and provide reports on the condition of leasehold pastoral lands. On behalf of the PLB, as at June 2009, NRETAS maintained a network of monitoring sites on over 200 properties across the NT that comprises 2222 Tier 1 and 99 Tier 2 sites. Karfs *et al.* (2001) provides a comprehensive review of the Tier 1 and Tier 2 monitoring programs.

Tier 1 monitoring sites are located on areas that are representative of the preferred pasture type or land system within a paddock or grazing area (Karfs *et al.* 2001). Thus the Tier 1 sites preferentially represent the better grazing lands and are not representative of a land system. "*Attributes assessed at Tier 1 sites include a fixed photograph and visual assessment of condition (good, fair, poor), a vegetation species list, percent of forage species or classes by dry weight, density of woody species, level of utilisation, percent bare ground, litter and vegetation and the presence or absence of noxious weeds*" (Karfs *et al.* 2001:17). Data collection for Tier 1 has recently been modified, see Current Monitoring, below.

Tier 2 sites, which are sampled more comprehensively, were designed to facilitate understanding of landscape function at a regional scale relating to change and trend detection using remote sensing through detailed and quantitative, though spatially limited, ground data (Karfs *et al.* 2001). According to Karfs *et al.* (2001), information from the Tier 2 system was also designed to enable separation of climatic induced landscape change from management induced change. For a comprehensive description of the selection and establishment of Tier 2 sites, and the collection, storage and analysis of the data collected in the tropical savannas, see Lynch and Karfs (2001). Currently data collection at Tier 2 sites has been suspended.

In 2008, the Australian Collaborative Rangeland Information System (ACRIS) released *Rangelands 2008 – Taking the Pulse* (Bastin G and the ACRIS, 2008), a comprehensive report which brought together data and information at a regional and national scale to describe changes in the rangelands across Australia. Each state and territory provided jurisdictional reports. The NT contributed the report *NT Information for the National Report: Rangelands 2007 – Taking the Pulse* (Mullin and Richardson 2007).

Program Intent
Regional monitoring of pastoral land condition using Landsat.

Data Storage
Oracle database, field sheets and digital photographs.

Extent
Tier 1: Grazed leasehold and some other tenured land across all regions of the NT. Tier 2: Victoria River District and Sturt Plateau regions of the NT.

Number of sites
As at June 2009, 2222 Tier 1 and 99 Tier 2 sites.

Current monitoring
The following is a summary of information from a meeting with Kate Richardson (Rangeland Monitoring – NRETAS) held in June 2009, information from the NRETAS website, and with reference to Appendix 3 which contains the current Tier 1 field data proforma.

The range of field data collected at Tier 1 sites has expanded since the program began with changes driven by research outputs from the Tier 2 program. A review of Tier 1 monitoring determined the minimum attributes that should be measured in the field should relate to satellite imagery and provide meaningful data towards describing the health of the landscape investigated (Anon, undated).

The main data types collected at each quadrat are:

- Species, cover levels and frequency of perennial butts

  - At each quadrat cover levels are recorded (visual estimates):
    - The percentage foliage cover for each species to the nearest 5%, attached plants are counted as plant cover even if senescent (species less than 5% cover)
    - The percentage of bare ground of the quadrat
    - The percentage of litter (including unattached plants within the quadrat)
    - The percentage of rock cover
    - The percentage of Crytogam cover
    - The total of all the above must equal 100%
    - For each perennial grass species recorded, the number of butts must recorded

- Recording of plant species present both within and in the immediate vicinity of quadrats
- Shrub and tree data is collected along the tape that is used for quadrat collection
- Tree density is measured from the site picket using a bitterlich gauge

The following description of the Tier 1 monitoring procedure has been modified from "Tier 1 Monitoring" – NRETAS website (Sourced 18 June 2009). http://www.nt.gov.au/nreta/natres/rangeland/monitor/tier1.html

"Monitoring sites comprise two steel pickets located 10 metres apart, about three to four kilometres from stock water and easily accessible from station tracks or fence lines.
A photograph is taken at the site from the sighting picket looking towards the central (tagged) picket. On establishment of site, a plant species is compiled

and relative proportion of major species assessed within a 50 metre radius of the central (tagged) picket. On future visits, the plant species are listed and the percentage (%) cover of each species recorded.
The information gathered includes

- *the date of the visit,*
- *location of site using a Global Positioning System*
- *General description of the site – e.g.: black soil plain, tall open woodland with grassy understorey etc*
- *Percentage of sand, gravel and rock present (visual estimation)*
- *Site's location in the landscape e.g.: crest, upper slope, mid slope, flat, stream channel etc*
- *Land system – type or unit if available*
- *Erosion - type and severity*
- *Colour of soil (dry only)*
- *Fire – time of year fire went through area, intensity, frequency*
- *Number of pasture species grazed by herbivores*
- *Utilisation – cattle activity*
- *Total grazing pressure on the resource – taking into consideration*
    - *the number of cattle*
    - *feral animals such as camels, donkeys, horses, rabbits*
    - *native species present including termites and kangaroos.*
- *Vegetation information – using recorded measurements of ground cover, trees, and shrubs gathered by using 1 m^2 quadrats at 5 m intervals along a 60 m transect from the photograph site picket.*
- *Other information gathered will include an estimated percentage of bare ground, organic litter such as fallen leaves and seed, and an estimation of rock covering the site.*
- *Tree density and the number and heights of shrubs within the transect"*

Site reassessment schedule

- Systematic
- Each Tier 1 site is now reassessed on a three year rotation. Each region is visited once every three years, with all sites within a region visited during same field season. Prior to 2007, there was no fixed schedule; rather a subset of sites from across all regions was reassessed each year with each site assessed once in every 2-3 years in the tropical north and every 3-5 years in the arid zone.
- Tier 2 sites are not currently being reassessed.

Comparison with SLATS

- Fixed sites
- Not representative of landscape. Sites are located on areas that are representative of the preferred pasture type or land system within a paddock or grazing area (Karfs *et al.* 2001)
- Site equals 50 m radius around central star picket
- Site description, collection of surface condition etc generally comparable – Tier 1 collects only dry soil colour, relative abundance and size only of coarse surface fragments (no colour / lithology)
- 1 x 50 m transect only

- Operator may choose quadrat based % cover visual estimate or whole site % cover visual estimates
- Operator may choose to estimate % cover or % standing biomass or count grass butts for surface cover description
- Single basal count only.
- All covers based on estimation which is affected by experience of data collector. SLATS uses point intercept method to minimise operator influence on data.
- Insufficient data to accurately and repeatedly quantify FPC, however, can estimate FPC.
- Insufficient data to quantify photosynthetic and non-photosynthetic material. Sites assessed in "Dry Season" when most non-woody ground covers likely to be senescent.

Potential use within proposed national land cover program

The Tier 1 data currently collected is not compatible with the SLATS methodology and is not suitable as input data for land cover / fractional cover classification.

Tier 1 data has fair to good potential for validating MODIS derived fractional cover and FPC products.

Although not currently collected, historical Tier 2 data has good potential for validating retrospective time series MODIS derived fractional cover and FPC products.

Further investigation is required into the relationship between the modified SLATS style assessment and Tier 1 data collection. It is proposed to trial both methods on a selection of Tier 1 sites later in 2009.

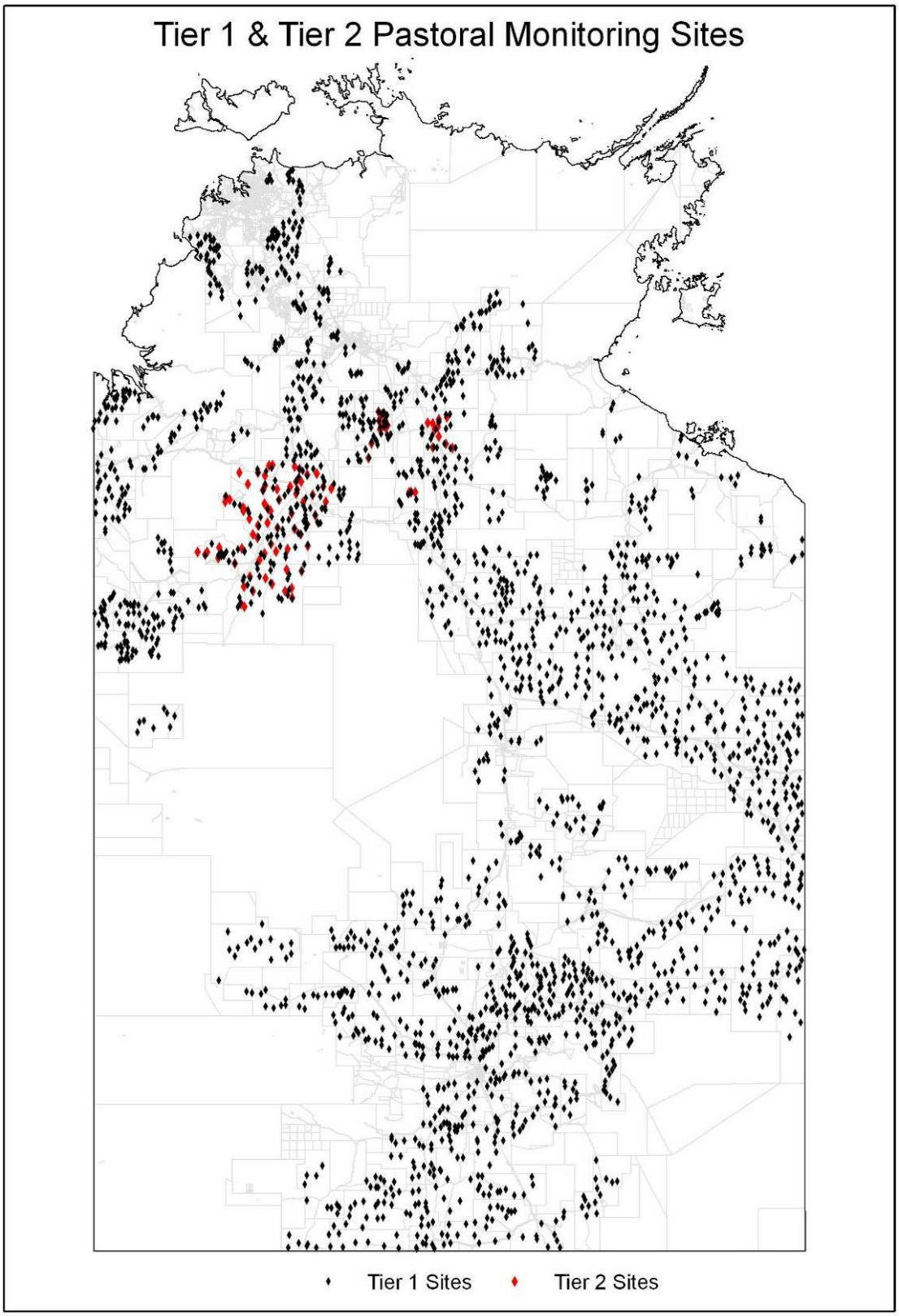

Figure 3 – Tier 1 and Tier 2 Pastoral Land monitoring site locations

3.6 Pastoral Land Monitoring – SwiftSynd

Overview

The SWIFTSYND pastoral land monitoring trial was established in 1993 with 21 sites to determine pasture model parameters for major productive land types of the Victoria River District (VRD) of the NT (Dyer *et al.* 2001). The majority of sites in the VRD ran from 1993 to 1996 (Dyer *et al.* 2001). A further 27 SWIFTSYND sites have been established on dominant productive land types in the Katherine, Sturt, Barkly and Alice springs areas. Although the modelled outputs have been validated for important production land types, some widespread vegetation communities, such as annual sorghum and spinifex pastures, are not represented (Dyer *et al.* 2001).

The objective of the data collection methodology was to specify a minimum data set from which relationships could be drawn to simulate pasture growth at a site using the Grass Production Model (GRASP) (Day & Philp 1997). The intent was to run the GRASP model for the widest possible range of communities and soil/species combinations throughout northern Australia. The same treatments were applied to each site include burning or mowing and subsequent harvesting (minimum of 4 per site/ year) to quantify pasture response to treatment (Day & Philp 1997).

Over 1998 and 1999, the *Aussie GRASS* project reported in Dyer *et al.* (2001) aimed to provide a modelling framework with the ability to objectively monitor and forecast seasonal variations in rainfall, pasture growth, total standing dry matter and grazing utilisation. Building on the detailed site data collected at the SWIFTSYND sites and Aussie GRASS included over 110,000 observation and validation sites across the NT and the Kimberley region of Western Australia (Dyer *et al.* 2001). This project has not been continued.

The SWIFTSYND methodology is described in Day & Philp (1997). Site selection was on the basis of uniform/ representative pasture and soil type, but generally avoided trees. Sites are fenced 50 x 50 m exclosures, with the soil and site described as per Macdonald *et al.* (1990)

The minimum data requirements include (Day & Philp 1997):

- Climate – daily and accumulated rainfall
- Soil – bulk density and gravimetric moisture content at 10cm increments in soil profile
- Soil texture/ colour
- Cover estimation per quadrat of green, dead, bare, litter and rocks
- Dominant species composition
- annual tree basal area using gauge collected at 4 corners and centre of site and dominant species recorded.
- Plant growth – quadrat based assessment
    - green and dead plant cover estimate at each harvest
    - dry matter yield of grasses and forbs per species (kg/ha)
    - pasture basal area
    - grass height

Program Intent
Input into GRASP to model pasture growth and estimate carrying capacity.

Data Storage
Field sheets and digital photographs.

Extent
Selected properties across grazed lands in NT.

Number of sites
28 as at June 2009.

Current monitoring
Quadrat based sampling as per Day & Philp (1997)

Site reassessment schedule
Systematic

Comparison with SLATS

- Fixed 50 x 50 m sites
- Sites not representative of the broader landscape, as less productive areas and woody areas generally excluded
- Sites not representative of land cover of broader landscape as contained within fenced exclosures
- Site treatments not reflective of land use of surrounding area
- Single annual tree basal count only. Results may be variable as Day & Philp (1997:p35) described a “home-made” Bitterlich angle-gauge which may have led to inconsistent counts.
- Unlike SLATS, sites can be correlated to local rainfall
- All covers based on estimation which is affected by experience of data collector. SLATS uses point intercept method to minimise operator influence on data.
- Insufficient data to accurately quantify FPC as trees avoided
- Data collected to quantify photosynthetic and non-photosynthetic material. Sites assessed in “Dry Season” when most non-woody ground covers likely to be senescent.

Potential use within proposed national land cover program
The SWIFTSYND data currently collected is not compatible with the SLATS methodology and is not suitable as input data for land cover / fractional cover classification.

SWIFTSYND data has no potential for validating MODIS FPC products but some potential for validating MODIS derived fractional cover products.

Although not currently collected, historical Aussie GRASS data may have potential for validating retrospective time series MODIS derived fractional cover products.

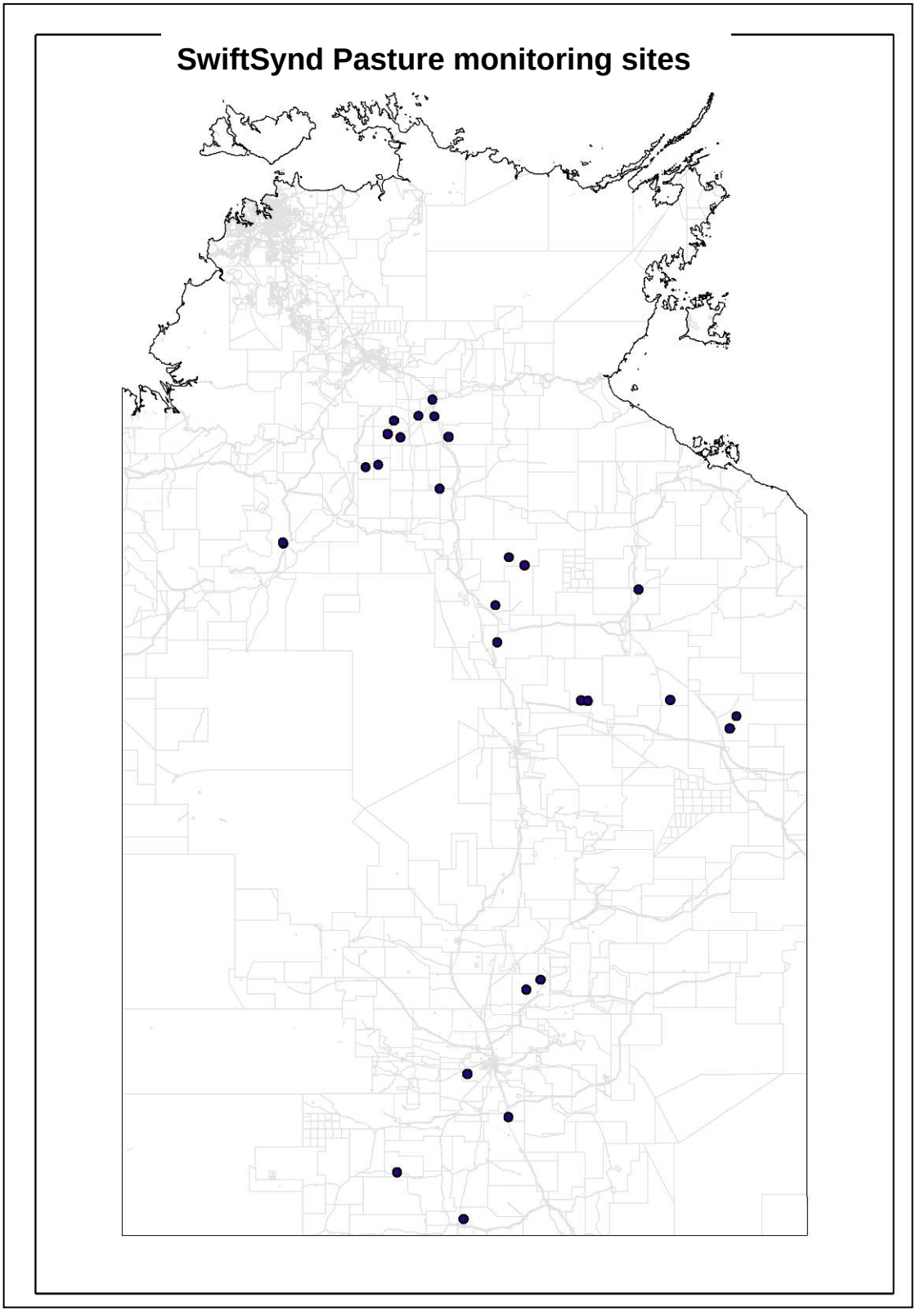

Figure 4 Location of SwiftSynd Pasture monitoring sites

4. Conclusion

No existing land cover monitoring program in the Northern Territory collects data that is compatible with the modified SLATS methodology. The only monitoring sites within the cropping area are sites associated with a trial soil condition monitoring program.

Comparison data collection trials are planned at selected Tier 1 and soil condition monitoring sites. Officers involved in both these programs have indicated that collection of SLATS compatible data would be separate and additional to the data already collected. It is possible that certain sites form the Tier 1 project may be suitable for inclusion in a national land cover project that includes the broader NT landscape, however further information as to the site location requirements and site characteristics needs to be provided to seriously assess this possibility. The situation is similar for the soil condition monitoring sites.

Collection of transect based point intercept cover data, similar to SLATS, is proposed for selected existing fire abatement sites. However, officers involved in this project have indicated that, due to the burning practices associated with this program, collection of additional data is not warranted and probably of limited value.

SwiftSynd data may provide insight into the response of land cover to climate.

Subject to the development of appropriate site selection criteria for proposed national land cover monitoring program:

c. New sites would need to be established in the agricultural areas of the NT.
d. Additional SLATS compatible data may be collected at selected Tier 1 monitoring sites; however, additional new sites may also be required.

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6. Appendices

Appendix 1 SLATS Field Sheet

Site Description

Site Number:_____ **Date:**_____

Zone:____ **Datum:**_____ **Easting:**_____ **Northing:**_____

Bearing (to GPS):_____ **Distance (to GPS):**_____

Film N^{o}:_____ **Photo N^{os}:**_____

Description:_____

_____

_____

Landform (**Cr**est; **Up**per; **Mi**d; **Lo**wer; **Fl**at; **Cl**osed; **Op**en)**:**_____

Slope %:_____ **Aspect:**_____

Soil Colour:

	Crust Dry	Dist. Dry	Adtnl. Dry	Crust Wet	Dist. Wet	Adtnl. Wet
Soil Hue						
Soil Value						
SoilChroma						

Cryptogam %:_____ **Cryptogam colour:**_____

Rock/Lag Colour:

	1st Dominant	2nd Dominant	3rd Dominant	4th Dominant	5th Dominant
Rock Hue					
Rock Value					
RockChroma					

Rock/Lag % est.:_____ **Biomass est. (kg/ha):**_____

Grass height (cm)**:**_____ **Fire:**_____

Faunal activity:_____ **Faunal type** (**Ca**ttle; **Sh**eep; **Ma**cropod; **Te**rmites; **An**ts; **Lo**cust)**:**_____

Crust Brokenness (**Ex**tensively broken; **Mo**derately broken; **Sl**ightly broken; **In**tact)**:**_____

Erosion Features (**Ri**lls; **Te**rracettes; **Sh**eeting; **Sc**alding; **Hu**mmocking; **Pe**destalling)**:**_____

Deposited Material (**Ex**tensive; **Mo**derate; **Sl**ight; **In**significant)**:**_____

Soil Microtopography (**Sm**ooth; **Sh**allow depressions; **De**eper depressions; **D**eep **f**ormations; **Ve**ry deep and extensive)**:**_____

Surface Nature (**No**n-brittle; **Ve**ry hard; **Mo**derately hard; **Ea**sily broken; **Lo**ose-sandy)**:**_____

Vegetation description:

	1st Dom by biomass	%	2nd Dom by biomass	%	3rd Dom by biomass	%
Overstorey						
Understorey						
Grasses/Forb						

Overstorey height: Observer:_____ **% Slope at 20m:**_____

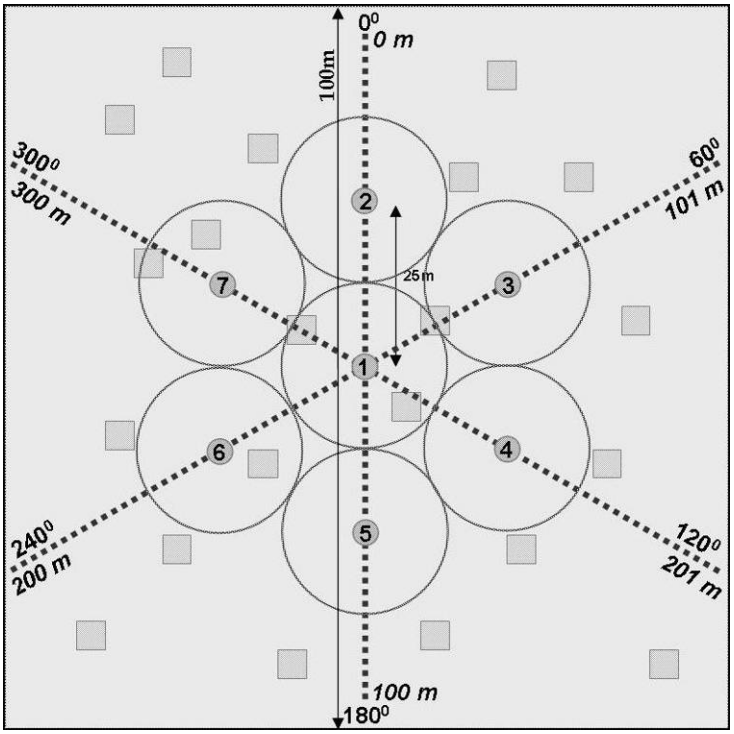
TBA:

	Prism factor	Observer	Live	Dead	Killed by fire	Converted
Centre 1						
North 2						
NE 3						
SE 4						
South 5						
SW 6						
NW 7						

Total Live TBA (Sum Converted TBA / 7)**:**_____**m^2/ha**

Weights: No. Q's:_____ **Total Wet Weight :**_____**g Sub Sample Wet Weight :**_____**g**

Sub Sample Dry Weight :_____**g TSDM :**_____**kg/ha**



Site Transect

Site Number:_____ Sheet Number:_____ Date:_____ Bearing:_____

Zone:_____ Datum:_____ Easting:_____ Northing:_____

	CRUST	DIST	ROCK	GREEN LF	DEAD LF	LITTER	CRYPT	MID GR	MID DE	MID BR	IN CRWN	OVER GR	OVER DE	OVER BR		CRUST	DIST	ROCK	GREEN LF	DEAD LF	LITTER	CRYPT	MID GR	MID DE	MID BR	IN CRWN	OVER GR	OVER DE	OVER BR
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2															52														
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Site Number:_____ Sheet Number:_____ Date:_____ Bearing:_____

Zone:_____ Datum:_____ Easting:_____ Northing:_____

	CRUST	DIST	ROCK	GREEN LF	DEAD LF	LITTER	CRYPT	MID GR	MID DE	MID BR	IN CRWN	OVER GR	OVER DE	OVER BR		CRUST	DIST	ROCK	GREEN LF	DEAD LF	LITTER	CRYPT	MID GR	MID DE	MID BR	IN CRWN	OVER GR	OVER DE	OVER BR
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Site Number:_____ Sheet Number:_____ Date:_____ Bearing:_____

Zone:_____ Datum:_____ Easting:_____ Northing:_____

	CRUST	DIST	ROCK	GREEN LF	DEAD LF	LITTER	CRYPT	MID GR	MID DE	MID BR	IN CRWN	OVER GR	OVER DE	OVER BR		CRUST	DIST	ROCK	GREEN LF	DEAD LF	LITTER	CRYPT	MID GR	MID DE	MID BR	IN CRWN	OVER GR	OVER DE	OVER BR
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Site selection criteria

Groundcover
- Sample the full range of cover from 0 to 100%.
- Sample a range of soil colours and textures.
- Sample a range of TBA from 0 to approx 10m^2/ha (although upper limit yet to be determined)
- Sample a range of understorey cover amounts.
- Ideally locate paired sites across fence lines sampling a contrasting cover on either side.

Tree & G. C.
- Locate in areas of uniform density and species mix for a minimum patch size of 300 x 300m if possible (larger if non DGPS).
- Locate a minimum of 100 metres from roads or other features not characteristic of the vegetation being measured (from the edge of site).
- Locate away from water run-on areas if possible.
- On level or near level ground.
- If a sloped site is necessary, avoid western and southern slopes (these are affected by shadow due to winter and morning sun angles).

Transect recording

- Minimum 300 sample points (100m transect tape x 3).
- Transect tapes laid strictly in a 0, 60 and 120 deg star pattern. The site centre is located at the intersection of the star.
- Measure in order of 0 – 180 deg, 60 – 240 deg and 120 – 300 deg for consistency.
- Averaged DGPS or GPS position at site centre (minimum 3-5min averaging for DGPS, longer for non DGPS). Recorded as UTM (Easting and Northing) with associated Zone and using default Datum WGS84. (Use UTM, Datum GDA94, Spheroid GRS1980 if available on GPS).
- Care should be taken to lay the tape out in a straight line - not dodging trees or shrubs.
- Care should be taken when placing the pole at each metre mark - read the ground cover first by looking vertically (or using a thin steel wire rod) above the tape thus avoiding crushing or moving a prospective grass/litter attribute. A laser pointer taped to the pole is more useful in areas with significant understorey e.g. heath.
- Before recording make sure both the observer and recorder are clear as to the classes being measured. Call in order of ground layer, mid layer, overstorey e.g. crust; mid (storey) green (leaf); crown; over (storey) branch.
- If recording hard copy sheets, care must be taken when reducing the measurements - have someone check the adding up and also the logic.
- If using a GRS Densitometer, both spirit levels must be centred and the recording spot centred in target circle.
- If using a gimballed sighting tube, the tube MUST BE FREE to ROTATE on the gimbal, otherwise operator bias WILL BE INTRODUCED.

Optical Wedges/Prisms

- When two people first go into the field they should both take BA wedge measurements at several sites to check if one or the other is systematically measuring more or less than the other [strict blind testing procedure advised].
- The possible reasons for bias are:
  - instead of counting every second "split" tree as “in”, the operator leaves all “out” or puts all “in”...(error = 0.5xthe number of "split" trees)
  - not keeping the wedge at the site centre – i.e. rotating the wedge around the body at arms length (error is most significant where site position is amongst bushes that may be counted as solid trunks if the wedge is close enough)
  - not looking behind large trees near the observer – can move off centre to check, keeping perpendicular...(error nil to quite large)
  - using the wrong thickness wedge relative to the tree/bush trunk thicknesses (error can vary depending upon site and or the operator)
  - poor eyesight - not being able to clearly see distant trees - thus leading to a preference for using a wedge that has a shorter measurement range (error generally in reading less trees than exist at the site)
  - not measuring/looking at the tree trunk at breast height – **1.3 m** (error depends on tree thickness but if looking low the counts will be higher than they should be)

The following table should be used to help select a suitable prism for a basal area measurement. Try to choose a prism which will give a plot radius of 15-20m. If the plot radius is larger make sure that its in a uniform area.

Plot radii (metres) as a function of prism factor and tree diameter

	Tree Diameter (m)					
Prism Factor	**0.1**	**0.3**	**0.5**	**0.7**	**1.0**	**1.5**
0.2	11	34	56	78	112	168
0.25	10	30	50	70	100	150
0.7	6	18	30	42	60	90
0.8	6	17	28	39	56	84
0.9	5	16	26	37	53	79
1.0	5	15	25	35	50	75
2.0	4	11	18	25	35	53
2.25	3	10	17	23	33	50
2.5	3	10	16	22	32	47

Optical Wedge Calibration

1. Set up a target such as a white board or wall at least 5 metres from where the wedge is held. Use up to 10 metres if you can see well as a greater distance is better.

2. Place a vertical line on the target using a marker pen. Hold the wedge at the measured distance (d) from the target and look through it at the line. Get a second person to draw another line, marking the displacement seen through the wedge.

3. Measure this distance (w) in the same units as (d).

4. Calculate the basal area factor as follows:

$$\text{Basal Area Factor (BAF)} = 1000/ (1+4*(d/w)^2)$$

where d = distance to target; w = displacement width e.g. d = 5m, w = 0.1m; BAF = 1.0

Appendix 2 Soil Condition Monitoring Field Data Sheet

Step-Point Ground Cover Assessment

Site: **Recorder:** **Date:**

Comments (incl current land use):

		Total		*Total*
Attached*				
Semi-detached*				
Detached*				
Gravel				
Bare				

Site: **Recorder:** **Date:**

Comments (incl current land use):

		Total		*Total*
Attached				
Semi-detached				
Detached				
Gravel				
Bare				

Site: **Recorder:** **Date:**

Comments (incl current land use):

		Total		*Total*
Attached				
Semi-detached				
Detached				
Gravel				
Bare				

Site: **Recorder:** **Date:**

Comments (incl current land use):

		Total		*Total*
Attached				
Semi-detached				
Detached				
Gravel				
Bare				

**Attached: Anchored to the ground; virtually immovable*

**Semi-detached: Connected to the ground, but able to shift around (e.g. fallen grass stem >20 cm from its roots)*

**Detached: No longer connected to the ground*

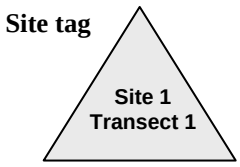
Appendix 3 Vegetation and Fuels Sampling Methodology

Source: Bushfires NT

A Site:
A **"site"** consists of **3 "transects"** each 100m in length, of variable width based on tree density (to sample a minimum of 20 stems), determined at site. The 3 replicate transects are selected, in unburnt country, to represent a similar set of parameters: vegetation community; fire regime; and topography.

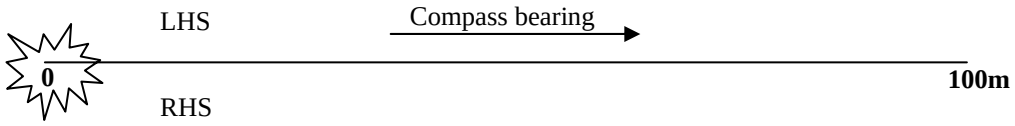
Transect Description:

- A description is made of the site including:
  the date, site#, transect#, width, vegetation community,
  surface soil type, 1:250k Land System, and fire regime.

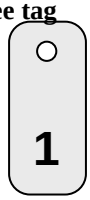


The Transect:

- For the start of each transect, a single tree is selected at random and permanently tagged, its GPS location noted:
  Easting; Northing; Zone; Datum; Date.
- A 100m tape is extended in a straight line, usually perpendicular to the nearest road, and the compass bearing in degrees noted.
- The width of the transect is variable, based on tree density (to sample a minimum of 20 trees. (e.g in open forest, 10 m width is appropriate; in heath 50 m)
- Dead standing stems are inventoried also.



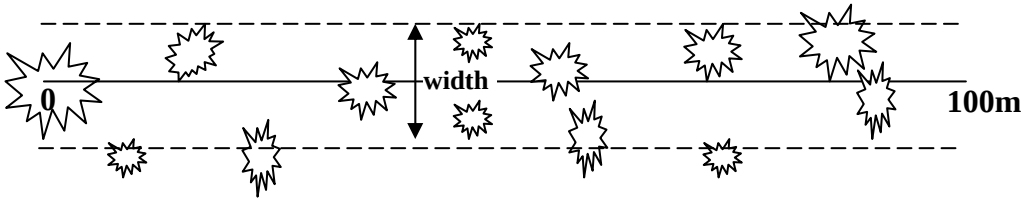
Upper Storey and Basal Area:



- The first 10 woody stems ≥ 5 centimetres diameter at breast height (dbh) [1.3m] within the determined width of the transect are permanently tagged and the following data collected: species, stem height, dbh, distance along transect, left or right side of transect, health status*

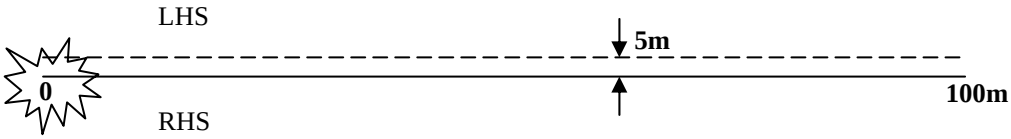
  *health status : 1 healthy (no dead branches) 2 :reasonable(some dead branches and fire scar)
  3 poor (deep fire scars and many dead branches) 4 :very poor (nearly dead) 5 dead.

- A further 10 woody stems ≥ 5 cm dbh within the width of the transect are sampled as before but **not** tagged.



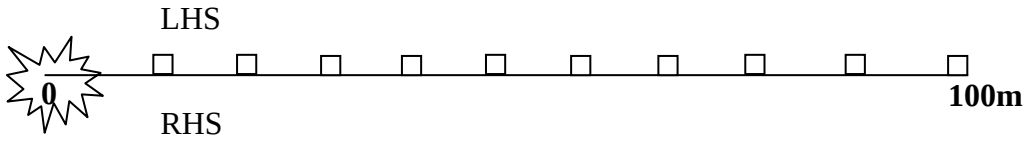
Heavy Ground Fuels:

- Along the left hand side, a 5 metre wide swath is sampled for dead stems ≥ 5 cm diameter on the ground. The length is measured in ranges: 0-50cm, 50cm-1m, 1-2m, 2-3m, 3-4m, 4-5m.If lengths are > 5m then sampling is undertaken in sections.
- The diameter of each stem is measured in ranges:
  5-10cm, 10-15cm, 15-20cm, 20-25cm, 25-30cm, 30-35cm, 35-40cm, 40-45cm, 45-50cm, > 50cm.
- The solid volume of stem material is allocated to 4 classes:
  a. 90-100%; b. 75-90%; c. 50-75%; and d. < 50%.



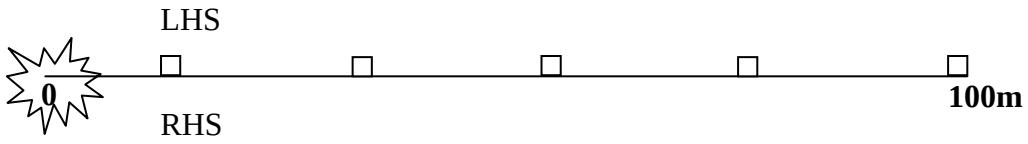
Coarse Ground Fuels:

- Ten 1 x 1 metre quadrats are sampled on the left hand side of the tape, commencing at 9m, at 10m intervals. All coarse ground fuels $\geq$ 6 mm and < 5 cm diameter are collected and weighed; a bulked sub-sample of the 10 quadrats is weighed and later dry weighed.



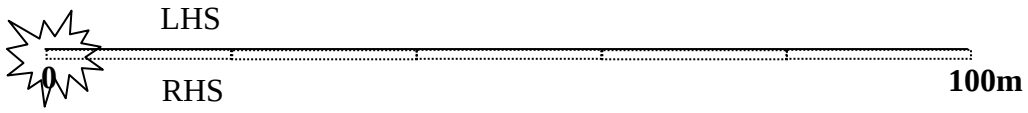
Fine Ground Fuels:

- Five 1 x 1 metre quadrats are sampled on the left hand side of the tape, commencing at 19 m, at 20m intervals. Grass and litter (including woody stems < 6 mm diameter) fractions are separately weighed; a bulked sub-sample of the five quadrats is weighed and later dry weighed.



Ground Cover and Canopy cover:

- Five 20 x 1 m sections on the right hand side of the tape are assessed for the following: %rock, %bare ground, %perennial graminoid cover (and dominant species names), %annual grass cover (and dominant species names), %shrub cover of woody species < 5 cm dbh (and dominant species names). Also a count and species identification of dominant woody species in the following size classes: < 50 cm high; 50 cm to 1m high; 1 to 2 m high; and > 2m but < 5 cm dbh.



- Tree canopy cover is measured for a 1 x 1 metre quadrat, at 5 metre intervals, along the whole length of the 100m tape. Values are: 0 - no cover; 1 - < 50% cover; 2 - $\geq$ 50% cover.

Standing Shrubs:

- 3 Samples of each dominant shrub species, per size class, (see above) will be cut and weighed, subsamples are taken and dry weighed.

Post Fire Effects:

- Transects are reassessed immediately after the site has been burnt. A 100m tape is laid out along the original compass bearing.
- Five, 20 x 1 m transects are assessed along the right hand side of the tape for the following: %burnt/patchiness (i.e. % of area), scorch height and char height, numbers of dead and living shrub stems per respective size classes (see above).
- The proportion of coarse fuel consumed is sampled in a 1m strip on the RHS of the tape; this 1m strip is divided into 5 x 20m lengths
- Heavy fuels are sampled in a 100m x 5m transect on the LHS; % burnt is estimated.
- Litter and ash are determined from 5, 1 x 1m quadrats on the LHS. Ash is vacuumed from a 25cm x 25cm quadrat in the top LH corner of the 1 x 1m quadrat. This residue is bagged, gross weight recorded and kept. The remaining litter within the 25x25 quad is collected, bagged and weighed.
- Within the 1 x 1m quad all litter, grass etc is collected and weighed (as per pre-fire methods), with a sub-sample collected at the end
- If any 1x1m quadrats are unburnt, the littler and grass measurements are recorded in a separate table on the datasheet

Appendix 3 Example Tier 1 Rangeland Monitoring Field Data Sheet

Source: Rangelands Management - NRETAS

TIER 1 SITE DESCRIPTION **RECORDING FORM**	Recorder/s:	Site No:

Date		Site Description and notes: (with brief description of soil/landform e.g. Mulga woodland on red earth plain; Mitchell grass on cracking clay plain; Coolibah & whitewood over short grasses & forbs on alluvial plain)

Landform			Aggregate		Munsell soil colour
Pattern	Slope (degrees)	Aspect	Abundance	Size	Dry

GPS Reference: WGS84 Zone …… E: …… N: ……

GDA94

Landform pattern type

ALF	*Alluvial fan*	MAD	*Made land*
ALP	*Alluvial plain*	MAR	*Marine plain*
ANA	*Anastamotic plain*	MEA	*Meander plain*
BAD	*Badlands*	MET	*Meteor crater*
BAR	*Bar plain*	MOU	*Mountains*
BEA	*Beach ridge plain*	PAR	*Parabolic dunefield*
CAL	*Caldera*	PED	*Pediment*
CHE	*Chenier plain*	PEP	*Pediplain*
COR	*Coral reef*	PNP	*Peneplain*
COV	*Covered plain*	PLA	*Plain*
DEL	*Delta*	PLT	*Plateau*
DUN	*Dunefield*	PLY	*Playa plain*
ESC	*Escarpment*	RIS	*Rises*
FLO	*Flood plain*	SAN	*Sand plain*
HIL	*Hills*	SHF	*Sheet-flood fan*
KAR	*Karst*	STA	*Stagnant alluvial plain*
LAC	*Lacustrine plain*	TER	*Terrace*
LAV	*Lava*	TEL	*Terraced land*
LON	*Longitudinal dunefield*	TID	*Tidal flat*
LOW	*Low hills*	VOL	*Volcano*

Aggregate

Coarse fragments on the surface

Abundance

0	*No coarse fragments*	0
1	*Very slightly; very few*	<2%
2	*Slightly; few*	2%–10%
3	*No qualifier; common*	10%–20%
4	*Moderately; many*	20%–50%
5	*Very; abundant*	50%–90%
6	*Extremely; very abundant*	>90%

Size

1	*Fine gravelly; small pebbles*	2–6 mm
2	*Medium gravelly; medium pebbles*	6–20 mm
3	*Coarse gravelly; large pebbles*	20–60 mm
4	*Cobbly; or cobbles*	60–200 mm
5	*Stony; stones*	200–600 mm
6	*Bouldery; or boulders*	600 mm–2 m
7	*Large boulders*	>2 m

TIER 1 **Disturbance** RECORDING FORM	Recorder/s: Date: / / 20	Site No:

NOTES AND GENERAL COMMENTS:
Seasonal Growth: Good / Fair / Poor
Season of Growth: Summer / Winter / Wet / Dry
Pasture Condition: Good / Fair / Poor

Disturbance	Proportion *	Age*
Storm damage	0 1 2 3	1 2 +
Road works	0 1 2 3	1 2 +

*Prop: 0 = 0; 1 = <1%; 2 = 1-5%; 3 = >5%
*Age: 1 = < 3 yrs (short term impacts still evident) 2 = > 3 yrs

Feral Activity
1 = No 2 = Yes

Type: Camels Rabbits Donkeys Horses

Floods
1 = yes 2 = no

Fire frequency	0 = absent 1 = incurrent season – last 3 months 2 = 1-2 years	Fire intensity	0=No damage 1=minor impact burn marks on some trees 2=moderate impact scars on most trees/shrubs 3=major scars on trees and shrubs 4=some trees & shrubs killed 5=most trees and shrubs killed

Erosion	Type; 0=none; 1=sheet; 2=rill; 3=gully; 4=tunnel; 5=stream; 6=mass Severity: 0 = absent; 1 = minor; 2 = moderate; 3 = severe

Grazing: (circle code)	0 = Nil (no grazing) 1 = Light occasional perennial grass grazed (<5% of growth removed) 2 = 25% of spp grazed (5-25% of growth removed) 3 = 50% of spp grazed, perennials, herbaceous and woody spp (25-50%) 4 = 75% of spp grazed, perennials, herbaceous and woody spp (50-75%) 5 = Heavy grazing of all perennials (>75% of growth removed) 6 = Most plants grazed low including less palatable spp 7 = Bare

Cattle Activity:	0 = Nil (no fresh sign of cattle) 1 = Occasional dung or trampling 2 = Regularly used cattle pads through site, some grazing, trampling and dung 3 = Well used cattle pads, trampling and grazing through site

SITE: DATE: / /20

Standing Dry Weight: Species ranked (as %) by their contribution to the total dry weight within the Quadrat. (Note: total for each Quadrat must be 100%; estimate percentage to nearest 5%; use K% if visually ranking dry weight across whole site instead of individual Quadrats.	Species name can be common name or scientific name. Cryptogram, Bare ground, Litter, Rock/Aggregate are recorded for each Quadrat when estimating Ground Cover. Use this to also list species occurring outside Quadrats.	Cover %: Using 1 metre quadrats, 10m past photo picket @ 5m intervals. (Note: Perennials and annuals to be recorded. Cover <5% to be noted as present using P; use G% if visual estimate of cover for whole site is used instead of individual quadrats; ID field is for collection number or code when a specimen is collected to aid ID) BUTT tally is for live butts only

Q10	Q9	Q8	Q7	Q6	Q5	Q4	Q3	Q2	Q1	K %	SPECIES	ID	G %	Q1 BUTT	Q2 BUTT	Q3 BUTT	Q4 BUTT	Q5 BUTT	Q6 BUTT	Q7 BUTT	Q8 BUTT	Q9 BUTT	Q10 BUTT
											Cryptogram												
											Bare Ground												
											Litter												
											Rock/Aggregate												
											TOTAL												

SITE: DATE: / /20

Q10	Q9	Q8	Q7	Q6	Q5	Q4	Q3	Q2	Q1	K %	SPECIES	ID	G %	Q1 BUTT	Q2 BUTT	Q3 BUTT	Q4 BUTT	Q5 BUTT	Q6 BUTT	Q7 BUTT	Q8 BUTT	Q9 BUTT	Q10 BUTT

SITE NO: DATE: / /20

WOODY SPECIES: (Record every tree and shrub within transect.)	SHRUB HEIGHT Use classes: 1 = <50cm 2 = 50cm to 2m; 3 = 2m-4m 4 = >4m	TAPE INTERCEPT: (Record in metres the mark along the tape at which the species starts and finishes)	
		Start	Finish

SITE: DATE: / /20

SPECIES (Note: select the BA Factor that most closely fits the trunk of the tree/shrub)	Basal Area Factor 0.25			Basal Area Factor 0.5			Basal Area Factor 0.75			Basal Area Factor 1.0		
	Full	Half	Total	Full	Half	Total	Full	Half	Total	Full	Half	Total

Appendix 5 Websites of groups / organisations that collect or display/disseminate land cover information

Australian Collaborative Rangeland Monitoring System (ACRIS)
http://www.environment.gov.au/land/rangelands/acris/index.html

North Australia Fire Information (NAFI)
http://138.80.128.152/nafi2/

More information about NAFI at Tropical Savannas Cooperative Research Centre
http://savanna.cdu.edu.au/savanna_web/information/downloads/NAFI-Doco.pdf

Department of Natural Resources, Environment, the Arts and Sport (NRETAS)
www.nt.gov.au/nreta/natres/

Bushfires NT
Vegetation Survey
NT Herbarium
http://www.nt.gov.au/nreta/contactus/natres.html

Rangelands Management
http://nt.gov.au/nreta/natres/rangeland/monitor/index.html

Biodiversity
http://nt.gov.au/nreta/wildlife/programs/staff/north/index.html

Department of Regional Development Primary Industry, Fisheries and Resources (DRPIFR)
http://www.nt.gov.au/d/

Grazing Land Management (GLM) within DRDPIFR
http://www.nt.gov.au/d/Primary_Industry/index.cfm?header=Grazing%20Land%20Management

Meat and Livestock Australia
www.mla.com.au

National Agricultural Monitoring System
www.nams.gov.au

North Australian Land Manager Website
www.landmanager.org.au/

Appendix 6 A selection of groups and agencies that collect data that may be useful for validating National Land Cover dataset.

This list is not exhaustive

Dept of Natural Resources, the Arts and Sport (NRETAS)

NT Herbarium	floristic and some community structural / cover information associated with botanical surveys
Biodiversity	floristic and some community structural / cover information associated with wildlife research and habitat mapping
Bushfires NT	some floristic and some community structural information with ground cover % / biomass associated with monitoring of fire effects
Rangelands Monitoring Section	floristic (mainly ground cover), ground cover and limited community description information associated with rangelands condition assessment and monitoring
Land and Vegetation Section	floristic and community structural information, since 2001 often includes cover % in all strata (sometimes quantitative point intercept FPC / ground cover similar to SLATS) associated with land resource and vegetation surveys.

Dept of Regional Development, Primary Industries, Fisheries and Resources (DRDPIFR)

Pastoral Branch (SwiftSynd)	floristic (mainly ground cover), ground cover/biomass and limited community description information associated with pasture growth and condition assessment / monitoring
Grazing Land Management (GLM) some data also collected by land managers	Basic floristic (mainly pasture species) / biomass, and (very) limited community description information associated with pasture growth and land condition assessment / monitoring