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CVAP Climate Variability in Agriculture R&D Program

Australian Grassland and Rangeland Assessment by Spatial Simulation

The Aussie GRASS

Northern Territory & Kimberley Sub-project

FINAL REPORT

April 2001

Queensland Government Natural Resources and Mines

Agriculture Western Australia

Northern Territory Department of Primary Industry & Fisheries

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South Australia

Land & Water Conservation

Queensland Government Department of Primary Industries

Australian Grassland and Rangeland Assessment by Spatial Simulation

(*Aussie GRASS*)

NT & Kimberley Rangeland Sub-project

QNR9

Final Report

for the

Climate Variability in Agriculture Program

April 2001

Rodd Dyer, Linda Cafe and Andrew Craig

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2 Introduction

The Aussie GRASS project provides a modelling framework with the ability to objectively monitor and forecast seasonal variations in rainfall, pasture growth, total standing dry matter and grazing utilisation. It has the potential to become an essential decision making tool for monitoring and managing grassland and rangeland condition throughout the Northern Territory (NT) and the Kimberley region.

This report will detail activities undertaken as part of the NT and Kimberley Rangeland sub-project of the Aussie GRASS project. As well, information collected or produced from complementary projects will be reported where appropriate. The activities in this sub-project can be divided into three broad groups: 1) development of model parameter sets using detailed data collected from exclosures; 2) collection of spatial biomass and related data; and 3) extension and communication activities. As well, a requirement across all three groups was the need to liaise with and provide feedback to collaborating agencies, in particular the Queensland Department of Natural Resources and Mines (NR&M).

Previous research funded by Meat and Livestock Australia (MLA) allowed parameter sets for the pasture growth model GRASP to be developed for 21 SWIFTSYND sites throughout the Katherine region. Generic parameter sets were derived for the land systems on which the SWIFTSYND sites were located for use within the spatial Aussie GRASS modelling framework. As many NT pasture communities have counterparts throughout the Kimberley region of Western Australia (WA), these parameter sets were also directly applicable to large areas of northern WA.

A significant component of the NT/Kimberley sub-project involved extensive collection of ‘spider mapping’ data. The collection of pasture biomass (or total standing dry matter

– TSDM) observations enabled the Aussie GRASS spatial model to be calibrated and validated for pasture communities throughout the NT and Kimberley regions. Between April 1998 and August 1999 over 110,000 visual observations of pasture biomass, greenness and grazing pressure were recorded.

Throughout the project, training and fieldwork were undertaken in a cooperative relationship between officers from the Northern Territory Department of Primary Industry and Fisheries (NTDPIF) and Agriculture Western Australia (AGWEST). Close collaboration with NR&M was necessary for data summary and analysis. The result of this substantial field data collection and analysis within a relatively short period is a working spatial pasture growth model for the NT and Kimberley regions. During this period the Aussie GRASS project and products were promoted to government agencies and land managers through both formal and informal communication and extension activities.

3 NT & Kimberley rangeland objectives

The NT and Kimberley sub-project had seven specific objectives within the Aussie GRASS project. These objectives, listed below, have been used to provide the basis for this report:

1. Complete calibration and validation of current SWIFTSYND / GRASP sites in the Victoria River District (VRD) and Katherine region of the NT.

2. Collection of an independent spatial validation data set for associated pasture communities throughout the Top End of the NT and the Kimberley WA.

3. Coordinate with NR&M in Queensland to carry out validation of spatial models of NT GRASP sites throughout the northern NT and the Kimberley.

4. Ground truth fire history maps generated from remotely sensed NOAA imagery.

5. Provide updated spatial data for modelling inputs including stock numbers, levels of utilisation, tree canopy cover and on-property rainfall.

6. Assist in the development of modelling products relevant to requirements in northern Australia and based on data collected in the NT.

7. Obtain training and provide opportunity for extension to end users of products that enable description and prediction of rainfall and climate variability, seasonal feed production, levels of utilisation and feed alerts.

4 SWIFTSYND sites in the Katherine region

As part of the MLA Sustainable Pasture Management project (NTA 022), 21 SWIFTSYND sites (Day and Philp 1997) were established throughout the Katherine region. These sites represent important pasture communities present in the NT and the

Kimberley, including tropical tallgrass, Mitchell grass, arid short grass, ribbon-blue grass and mid-height tussock grass pastures in a range of rainfall zones and pasture conditions.

The calibration of GRASP for each site has been completed and thus provides a working pasture growth model for each site. The SWIFTSYND sites have also been categorised according to the dominant pasture and soil type. On the basis of this categorisation, Ken Day (NR&M), Michael Cobiac and Rodd Dyer (NTDPIF) have developed generic parameter sets for major pasture/soil systems (Table 1). These generic parameter sets have then been used to help derive parameter values in the Aussie GRASS spatial model.

A more detailed report on the derivation of these generic parameter sets is provided in Appendix 1.

5 Spider mapping

The 'spider mapping' sampling technique (Hassett *et al.* 2001) was originally developed in the first phase of the Aussie GRASS project (Brook *et al.* 1996). The method allows for the collection of large spatial data sets of understorey biomass from a moving vehicle for the purpose of calibration and validation of the Aussie GRASS model. The method used throughout the NT and Kimberley sub-project was a modified version of this technique.

Prior to spider mapping in the NT and Kimberley, training of both NTDPIF and AGWEST staff in sampling techniques was undertaken at Kidman Springs over several days under the guidance of Rob Hassett from NR&M. Retraining and recalibration in biomass estimation were also carried out prior to each series of trips, and whenever a new observer became involved. Due to a number of differences between Queensland and the NT, some changes were made in sampling method to suit local conditions. The main difference was a reduction in the number of calibration harvests made each day. Throughout sampling in the NT, approximately 5-6 calibration sites were selected and measured each day, with data over a two-day period being used to calibrate visual estimates. The software used to collect and display the data also differed from that reported by Hassett *et al.* (2000).

5.1 Method

Spider mapping is a method which allows a large number of standing pasture biomass estimations to be collected. Observations of standing biomass, as well as pasture greenness and grazing pressure, were made continuously from a moving 4WD vehicle while travelling along a predetermined route. All measurements were conducted with two officers. Both the driver and passenger made several sets of observations each minute from their respective sides of the vehicle. The passenger entered all data directly into a laptop computer. The sampling speed was determined primarily by the road surface condition and the field of view into the adjacent area. Visibility from major roads in some areas was poor due to large ungrazed roadside verges. Well-maintained public and station dirt roads were most efficient in terms of distance travelled and observations recorded per day. These roads also had less 'edge' effect compared to more developed roads.

Each observation covered a field of view of approximately one hectare where visibility allowed, although at times this was reduced due to escarpments, tall pastures and dense trees. Good quality light was found to be essential to ensure consistent observations. This required work to begin approximately an hour after sunrise and stop an hour before sunset. The pasture community and condition were recorded each time the community changed. Other occasional observations included fire scar observations, and stock and feral animal observations.

5.1.1 Computer/GPS setup

A Toshiba laptop computer (486, 133Mhz, with active matrix screen) connected to a Trimble Geoexplorer II GPS and Trimble Aspen software (© 1996, 1997 Trimble Navigation Limited) were used to enter all data. The type and format of desired data input variables were initially defined in data dictionaries using Trimble Pathfinder software (© 1996-1999 Trimble Navigation Limited). This allowed continuous geo-positioning and collection of spatial information as the passenger entered observations during travel. Background digital maps of roads and pastoral infrastructure were displayed on the computer screen, along with current location and a trail of points showing where each observation had been recorded. This prevented 'geographical embarrassment', particularly when following tracks that hadn't been graded for several years. Some problems were encountered with satellite availability at various times of the day, however these were generally of short duration. No technical difficulties due to failure of the computer/GPS setup or data transfer were encountered. The data were collected and saved onto the hard drive in two files each day, and these files were regularly backed up onto floppy disk. Data files were stored in Trimble Aspen as 'rover' files, and were simply exported as shape files for viewing in ArcView (© 1992-1998 ESRI) or ASCII files for data summary in Excel (© 1985-1997 Microsoft Corporation).

5.1.2 Calibration sites

Collection of more detailed vegetation data was carried out at several calibration sites each day. Initially about ten sites per day were planned, however time restrictions caused this to be reduced to five to six in the NT. In the Kimberley, less detailed information was collected at each site and ten sites were collected each day as planned. Calibration sites were selected to represent the range of biomass and communities observed during the day. Sites were estimated visually and then sampled to allow calibration of biomass observations. Each observer estimated standing biomass, pasture greenness and grazing pressure before leaving the vehicle. Six to ten 1 m^2 quadrats were then cut in a line at right angles to the road, through the centre of the estimated hectare, with more quadrats being cut on less homogenous sites. Quadrats were spaced about ten paces apart to ensure a good coverage of the area. At each quadrat the percentage cover of perennial and annual grass, dicots and bare ground were also estimated.

The quadrats were cut using Makita electric shears, placed in a 20 l bucket and weighed on a portable digital balance (2,000 g x 1 g). A bulked subsample was collected for dry matter and nutrient analysis. Litter was collected for each quadrat, bulked and weighed to be included in calculations of fire fuel load.

In the NT these sites were also used to collect other community data. The sites were photographed, and pasture community, soil colour, slope and aspect recorded. Tree basal area and height (dendrometer) were measured, and crown type and crown cover estimated. The three dominant species in the upper and middle tree storeys, and the pasture layer were also recorded. A recording sheet (Figure 1) was used to record the calibration site observations.

5.2 Analysis of data

5.2.1 Observation data

Trimble rover files were combined to correspond to the appropriate calibration harvests, and exported as shape and ASCII files. The shape files were used in ArcView to produce maps of the trip data. The ASCII files were imported into spreadsheets for initial processing and then dispatched to NR&M for further analysis.

5.2.2 Calibration site data

The calibration site harvest biomass data were used to produce regressions between observed and actual biomass for each observer (using Jandel Tablecurve © 1989-1996 AISN Software Inc.). These equations were then applied to the observed spider mapping data to produce an adjusted biomass observation. Normally at least ten sites were used for each correlation. In instances where correlations were poor ($r^2<0.70$), the estimated biomass data for the corresponding period were rejected. This only occurred on one occasion for one observer throughout all NT trips. On most occasions r^2 values over 0.9 were obtained for regression between observed and predicted values of biomass. All results reported here show the adjusted values.

All remaining information from the calibration sites, including the photographs, were stored in a Microsoft Access database (© 1992-1999 Microsoft Corporation) (see Figures 2-4). These data has been used to summarise some characteristics of the areas studied (see Table 1). The locations of the calibration sites are shown in Figures 5 and 6 for the NT and Kimberley respectively.

5.3 Results

Extensive spider mapping was undertaken throughout the NT and Kimberley between April 1998 and September 1999. Fieldwork was carried out over a total of 16 trips and 117 days. A total of 18,000 km was traversed in the NT alone. Over 110,000 observations of pasture biomass, greenness and grazing pressure were made between both agencies (87,000 NT; 25,000 Kimberley). Observations of pasture community type, fire scars and feral animals were also recorded. Detailed calibration data was collected for 567 sites (268 NT; 299 Kimberley).

In 1998 a similar route through the VRD and eastern Kimberley was sampled during both the early and late dry seasons. In 1999 a more comprehensive survey was undertaken across the entire NT and Kimberley region. Spatial biomass data were summarised according to bioregion, vegetation type and land tenure to obtain an overview of pasture biomass distribution.

Spatial Validation - Calibration Site Recording Sheet

Site No.	Date	Time
Easting	Northing	Altitude

Slide No.	Photo No.	Digital Photo No.

Aspect	Slope	Transect
Vegetation Community		
Soil Colour		

Species Composition

Dominant	Upper Storey	Middle storey	Pastures
1			
2			
3			

Woody Vegetation Data

	Crown Type	Crown Cover	Height	Basal Area
Middle Storey				N/A
Upper Storey				

Pasture Estimations

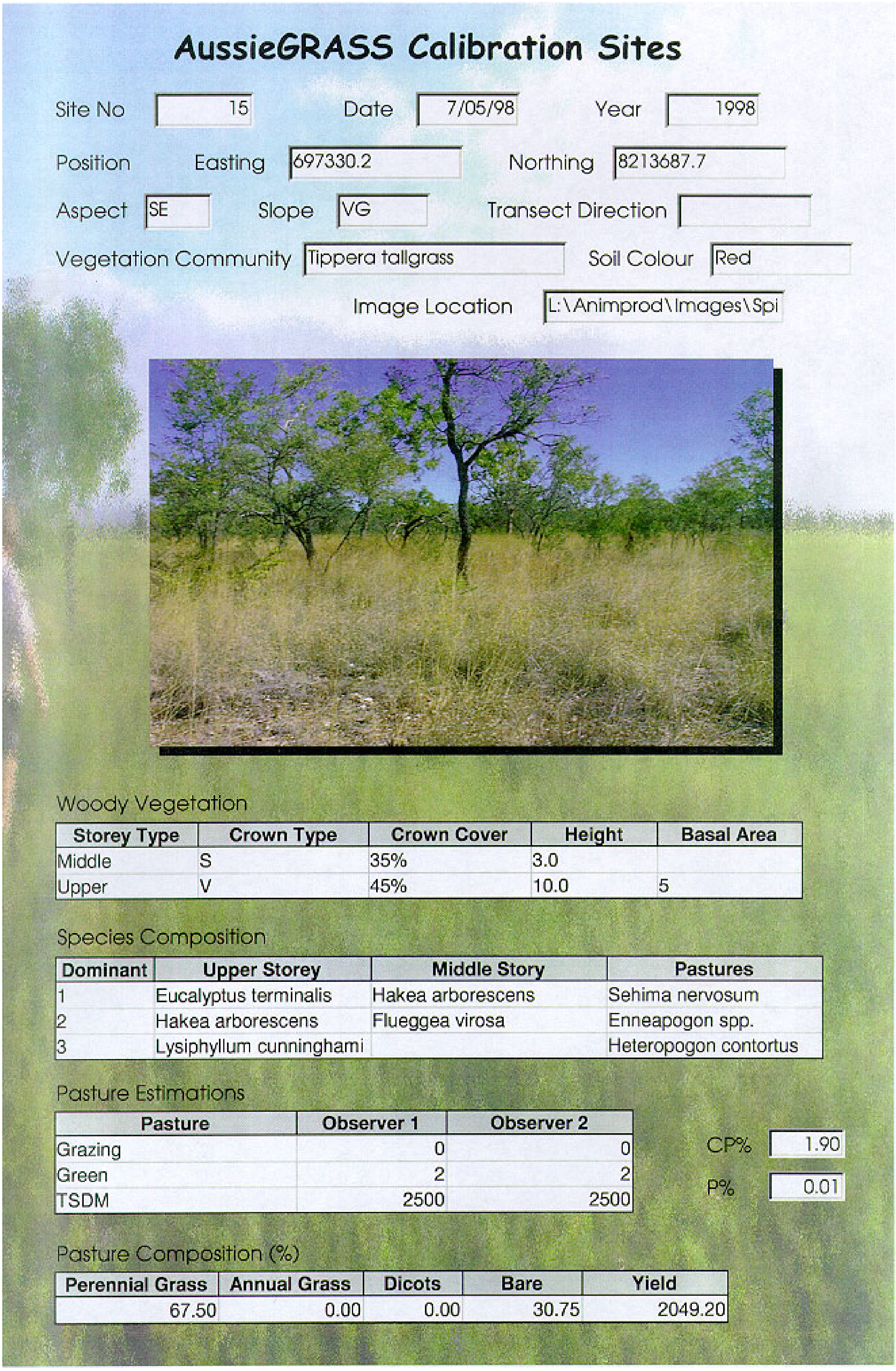
	Observer 1	Observer 2
TSDM		
Green		
Grazing		

Quadrat Pasture Measurements

	Cover				
Quadrat	Perennial Gr	Annual Gr	Dicots	Bare	Yield
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Average					

Comments____

Figure 1. Recording sheet used for NT calibration sites in 1998 and 1999.



AussieGRASS Calibration Sites

Site No 15 Date 7/05/98 Year 1998

Position Easting 697330.2 Northing 8213687.7

Aspect SE Slope VG Transect Direction

Vegetation Community Tippera tallgrass Soil Colour Red

Image Location L:\Animprod\Images\Spi

Woody Vegetation

Storey Type	Crown Type	Crown Cover	Height	Basal Area
Middle	S	35%	3.0	
Upper	V	45%	10.0	5

Species Composition

Dominant	Upper Storey	Middle Story	Pastures
1	Eucalyptus terminalis	Hakea arborescens	Sehima nervosum
2	Hakea arborescens	Flueggea virosa	Enneapogon spp.
3	Lysiphyllum cunninghami		Heteropogon contortus

Pasture Estimations

Pasture	Observer 1	Observer 2
Grazing	0	0
Green	2	2
TSDM	2500	2500

CP% 1.90

P% 0.01

Pasture Composition (%)

Perennial Grass	Annual Grass	Dicots	Bare	Yield
67.50	0.00	0.00	30.75	2049.20

Figure 2. Example of database form for Site 15 VRD, 1998.

AussieGRASS Calibration Sites

Site No: 22 | Date: 20/04/99 | Year: 1999

Position — Easting: 424126.15 | Northing: 7155447.06

Aspect: SW | Slope: VG | Transect Direction: SW

Vegetation Community: Spinifex | Soil Colour: Red sand

Image Location: L:\Animprod\Images\Spi

Woody Vegetation

Storey Type	Crown Type	Crown Cover	Height	Basal Area
Middle	V	30%	2	
Upper	I	65%	9	0

Species Composition

Dominant	Upper Storey	Middle Story	Pastures
1	Eucalyptus terminalis	Grevillea spp	Triodia spp
2		Acacia spp	Eriachne spp
3			Dicots

Pasture Estimations

Pasture	Observer 1	Observer 2
Grazing	1	3
Green	1	1
TSDM	3000	1800

CP%

P%

Pasture Composition (%)

Perennial Grass	Annual Grass	Dicots	Bare	Yield
35.83	0.00	2.50	61.67	3817.15

Figure 3. Example of database form for Site 22 Alice Springs region, 1999.

AussieGRASS Calibration Sites

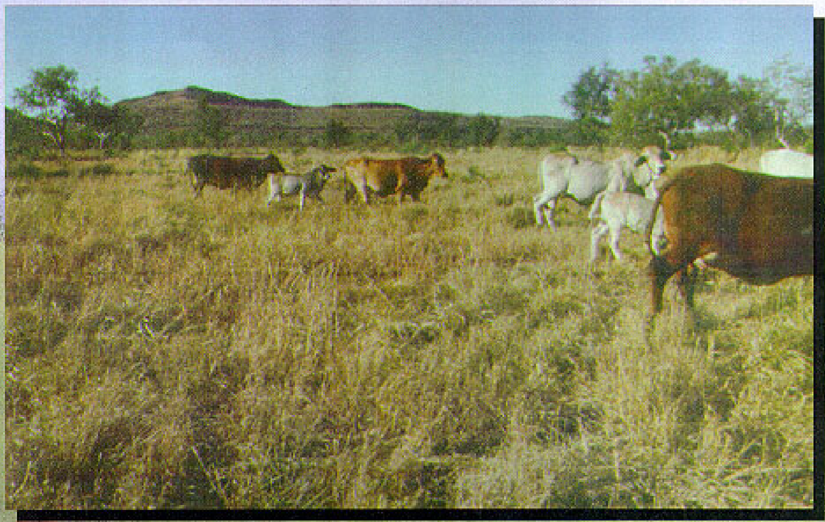
Site No: 51 | Date: 28/05/98 | Year: 1998

Position: Easting: 523157.3 | Northing: 823034.7

Aspect: | Slope: Flat | Transect Direction:

Vegetation Community: Ribbon/blue grass | Soil Colour: Black

Image Location: L:\Animprod\Images\Spi



Woody Vegetation

Storey Type	Crown Type	Crown Cover	Height	Basal Area
Upper	V	30%	7.9	0
Middle	V	55%	2	

Species Composition

Dominant	Upper Storey	Middle Story	Pastures
1	Lysiphyllum cunninghami	Lysiphyllum cunninghamii	Chrysopogon fallax
2	Eucalyptus terminalis	Carissa lanceolata	Dichanthium fecundum
3	Eucalyptus pruinosa		Iseilema spp

Pasture Estimations

Pasture	Observer 1	Observer 2
Grazing	3	3
Green	1	1
TSDM	1500	1500

CP% 3.10

P% 0.03

Pasture Composition (%)

Perennial Grass	Annual Grass	Dicots	Bare	Yield
45.00	25.00	3.33	24.92	1401.18

Figure 4. Example of database form for Site 51 VRD, 1998.

Table 1. NT calibration site vegetation summary.

Vegetation community	Count	Mean annual grass cover (%)	Mean perennial grass cover (%)	Mean dicot cover (%)	Mean bare cover (%)	Mean P (%)	Mean CP (%)	Mean yield (kg DM/ha)
Annual sorghum	20	25.7	13.5	1.6	59.1	0.01	1.20	1484.7
Arid short grass	59	13.4	22.0	2.7	59.7	0.03	3.09	663.0
Mitchell grass	45	13.5	36.2	2.6	49.4	0.04	3.84	1539.6
Mulga	8	41.7	12.6	2.9	84.0			280.1
Perennial tallgrass	45	3.7	43.6	1.2	51.5			1967.5
Ribbon/blue grass	27	13.9	51.5	3.4	30.2	0.02	2.65	2319.0
Schizachyrium	4	21.5	25.2	8.3	45.0			851.2
Spinifex	39	0.6	39.2	1.2	58.3	0.03	3.54	2369.0
Tippera tallgrass	11	6.8	59.2	1.9	31.1	0.02	2.23	2515.2

5.3.1 Northern Territory

Spatial validation trips were carried out in 1998 and 1999. In 1998 the VRD was sampled at the end of the wet season, and the same route followed again at the end of the dry season. The route was designed to thoroughly cover the VRD along the rainfall gradient that exists from north to south. In 1999 the focus of the spider mapping was broadened to the whole of the NT with all major pasture communities visited once (Figure 7). Details of the four 1998 trips and the five 1999 trips are shown in Table 2.

Table 2. Details of spatial validation trips carried out in the Northern Territory in 1998 and 1999.

Year	Trip	No of observations	Days per correlation	Duration of trip	Observer	Mean r^2	No of sites
1998	SthnVRD	10912	2.6	5-14 May	LMC	0.874	30
					JAW	0.799	30
	NthnVRD	8028	1.8	25-29 May	LMC	0.909	20
					JAW	0.863	20
	SthnVRD	13784	3.3	19-29 Sep	LMC	0.969	33
					KDN	0.908	33
	NthnVRD	9819	2.0	19-23 Oct	LMC	0.971	20
					JAW	0.923	20
1999	Alice Springs	14352	2.5	15-26 April	LMC	0.968	45
					SMM	0.946	43
	Tennant Creek	7816	2.7	10-17 May	LMC	0.956	27
					SMM	0.933	26
	Borroloola	6637	2.0	2-6 June	LMC	0.961	24
					SMM	0.954	23
	Arnhem Land	7987	2.7	30 June-7 July	LMC	0.945	32
					SMM	0.863	32
	SthnVRD	3257	3.0	10-15 August	TJO	0.930	22
					SMM	0.879	22
	NthnVRD	4188	2.0	23-26 August	LMC	0.950	16
					SMM	0.932	16

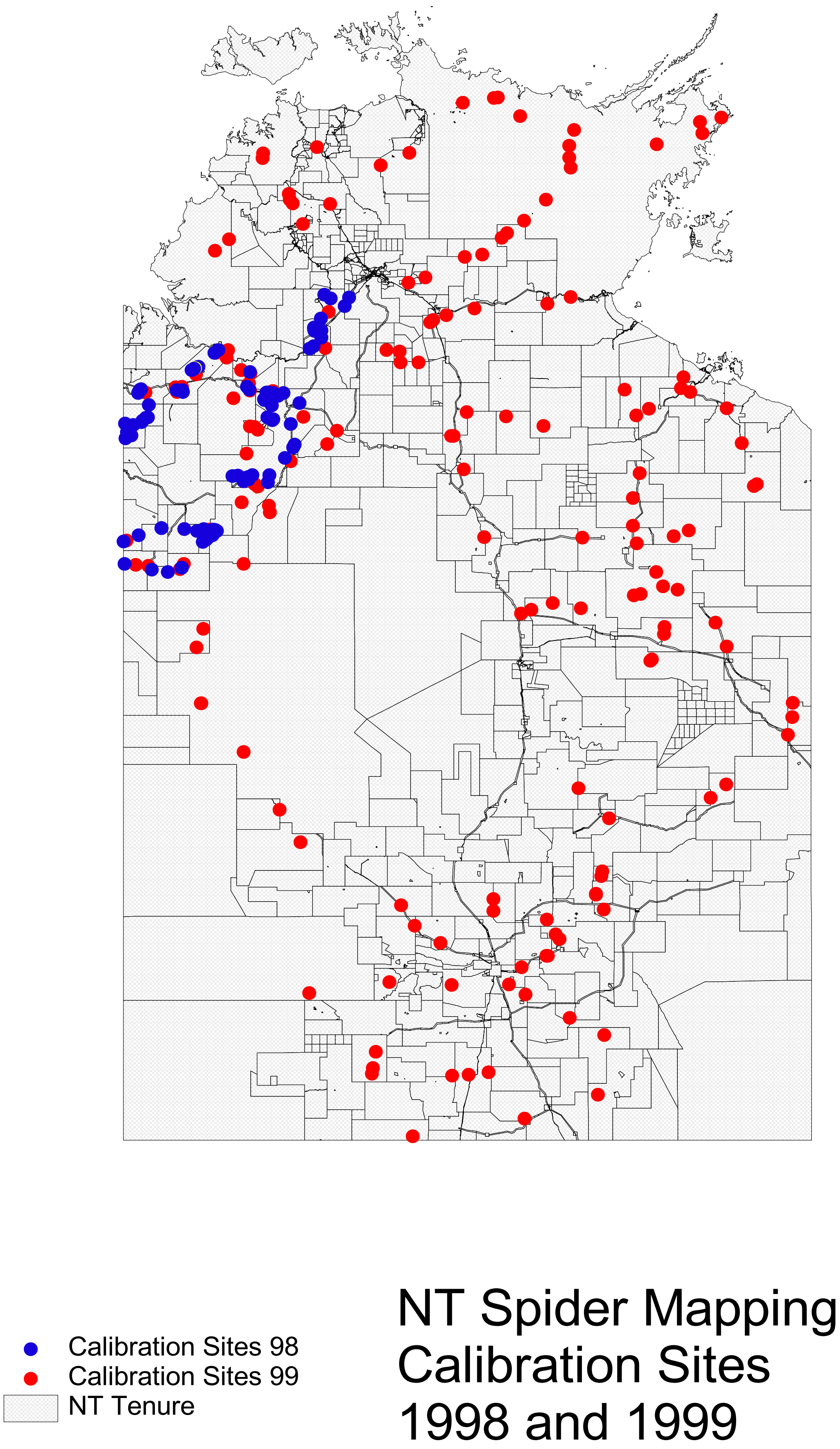


Figure 5. NT spider mapping calibration sites, 1998 and 1999.

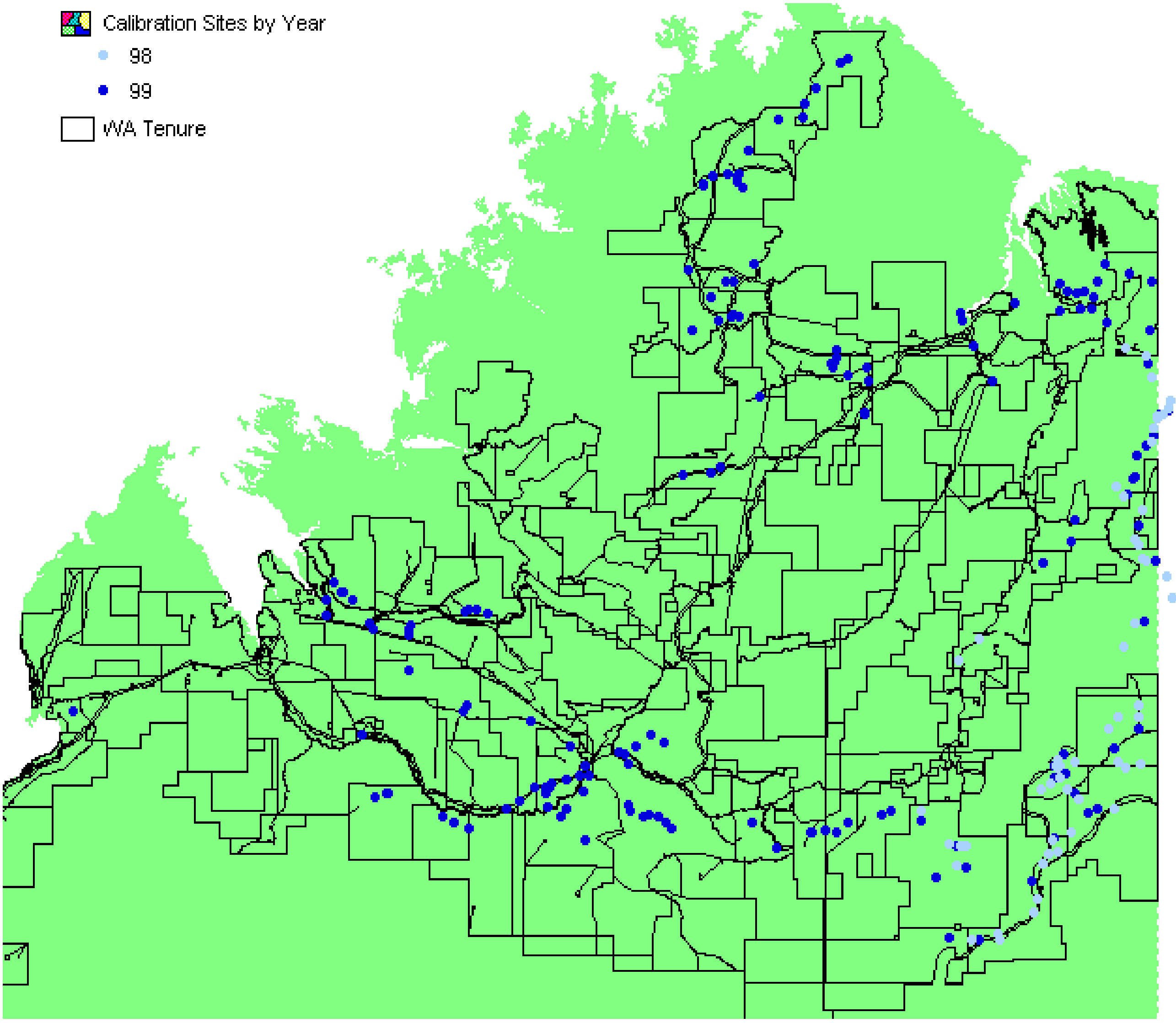


Figure 6. Kimberley spider mapping calibration sites, 1998 and 1999.

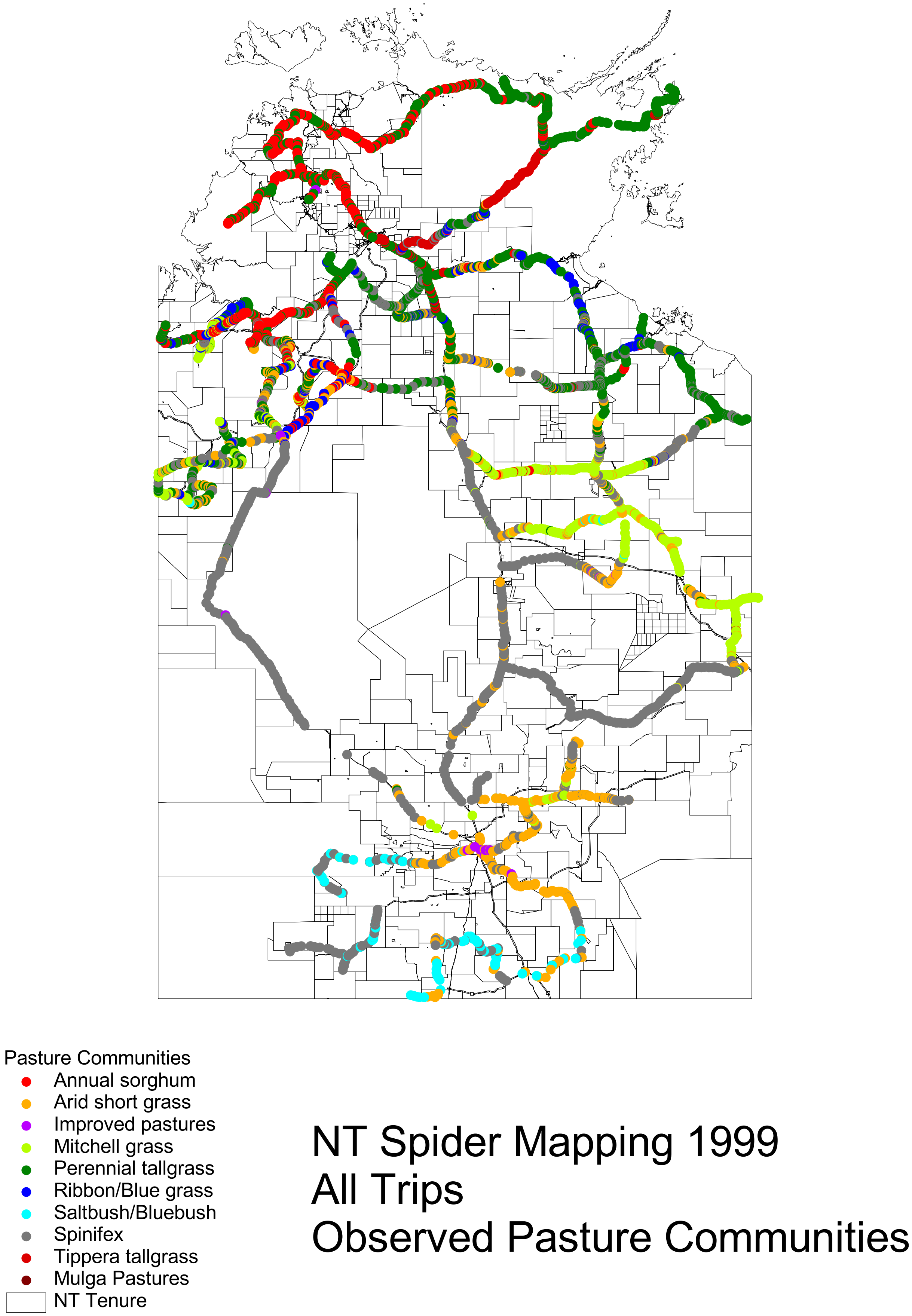


Figure 7. NT pasture communities visited during 1999 spider mapping.

5.3.1.1 VRD - 1998

The sampling route and values for standing biomass, grazing pressure and pasture greenness observations for the early dry (May) and late dry (September) field surveys in the VRD for 1998 are shown in Figures 8-13 with data points overlaid on lease boundaries. Significant spatial and temporal variations in biomass, grazing and greenness parameters were observed. Average biomass values within the VRD for bioregions and land tenures are shown in Tables 3 and 4 respectively. Changes in biomass between the early and late dry seasons were lower on the Sturt Plateau than other regions, indicating a lower grazing pressure. The locations of NT bioregions are shown in Figure 14. A 30% reduction in average yield between early and late dry seasons was observed. Most field observations (85-87%) were made on pastoral land. In general pasture biomass was lowest on crown land and pastoral land during both the early and late dry. On pastoral land, the late dry season yield was 25% less than during the early dry.

Table 3. Average standing biomass (TSDM: kg DM/ha), observations (n) and mean standard error (SEM) measured for VRD bioregions in the early dry season and late dry season, 1998.

Bioregion	Early Dry Season			Late Dry Season		
	TSDM	n	SEM	TSDM	n	SEM
Daly Basin	1836	766	39	832	737	32
Ord-Victoria	1363	14150	8	1068	18561	6
Sturt Plateau	1161	378	47	1027	373	37
Victoria-Bonaparte	1175	3406	15	617	3436	11

Table 4. Average standing biomass (TSDM: kg DM/ha), observations (n) and mean standard error (SEM) measured for VRD land tenure in the early dry season and late dry season, 1998.

Land Tenure	Early Dry Season			Late Dry Season		
	TSDM	n	SEM	TSDM	n	SEM
Other	1594	1036	30	1231	1458	24
Crown Land	1019	535	39	508	552	25
Freehold	2128	965	35	1519	1547	22
Pastoral	1294	16404	8	966	20046	6

The distributions of standing biomass, biomass greenness, and grazing pressure in 1998 for the VRD during the early and late dry season are shown in Figures 15-17. Similarly, grazing pressure and standing biomass distributions for the four classes of tenure are shown in Figures 18 and 19. Lower yields and heavier grazing pressure were observed in the late dry season for all bioregions, particularly on crown and pastoral land. The highest frequency of yields less than 500 kg DM/ha occurred on crown lands.

Differences in grazing pressure between regions were obvious during the dry season. Grazing pressure was generally lighter throughout the Sturt Plateau in the late dry compared to other regions, in particular the Victoria–Bonaparte. During the early dry season the distribution of pasture greenness observations throughout the Daly Basin was noticeably different from other regions, with pastures being greener during this period. By the late dry the distribution of greenness was similar among all bioregions.

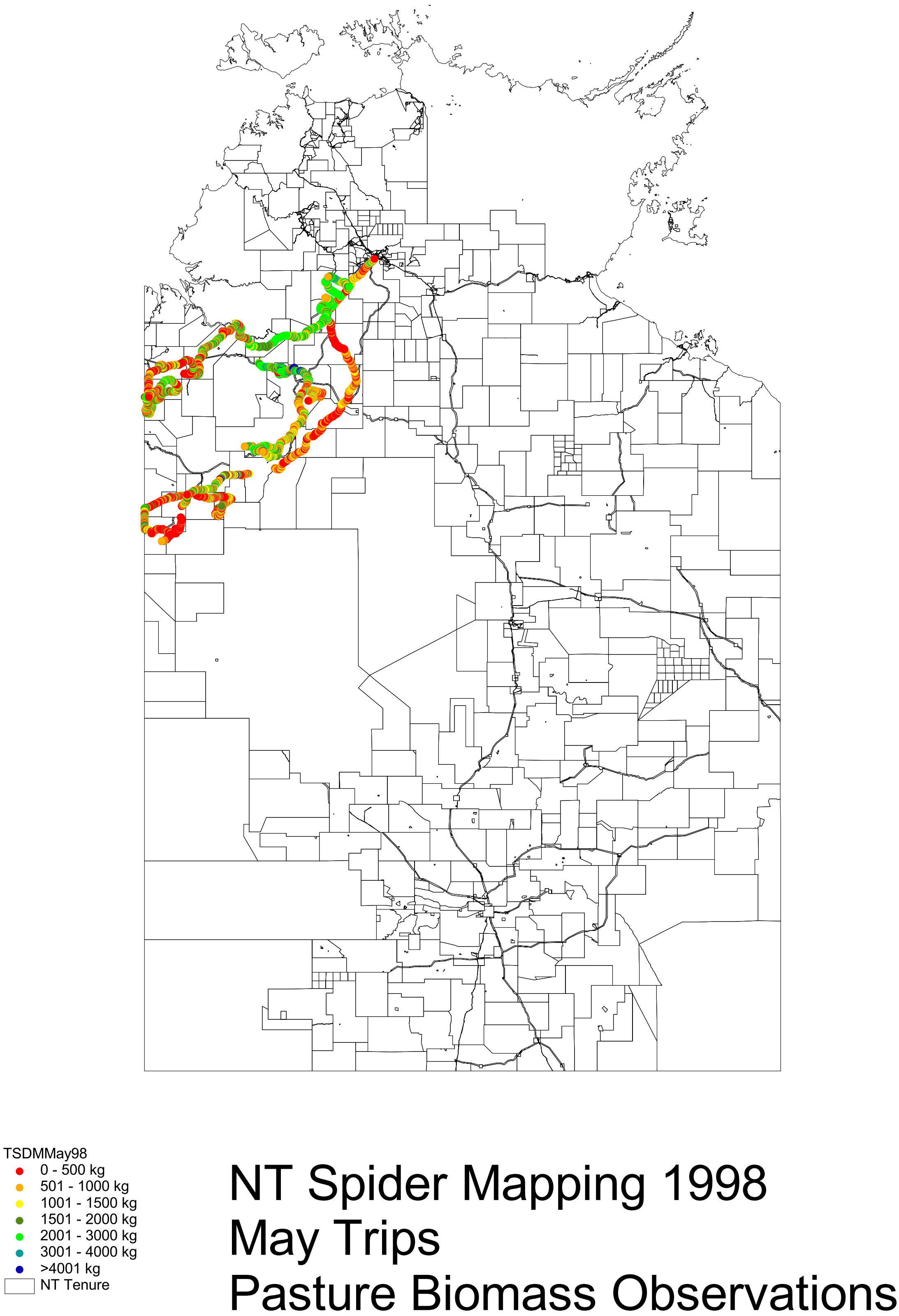


Figure 8. NT spider mapping biomass observations, May 1998.

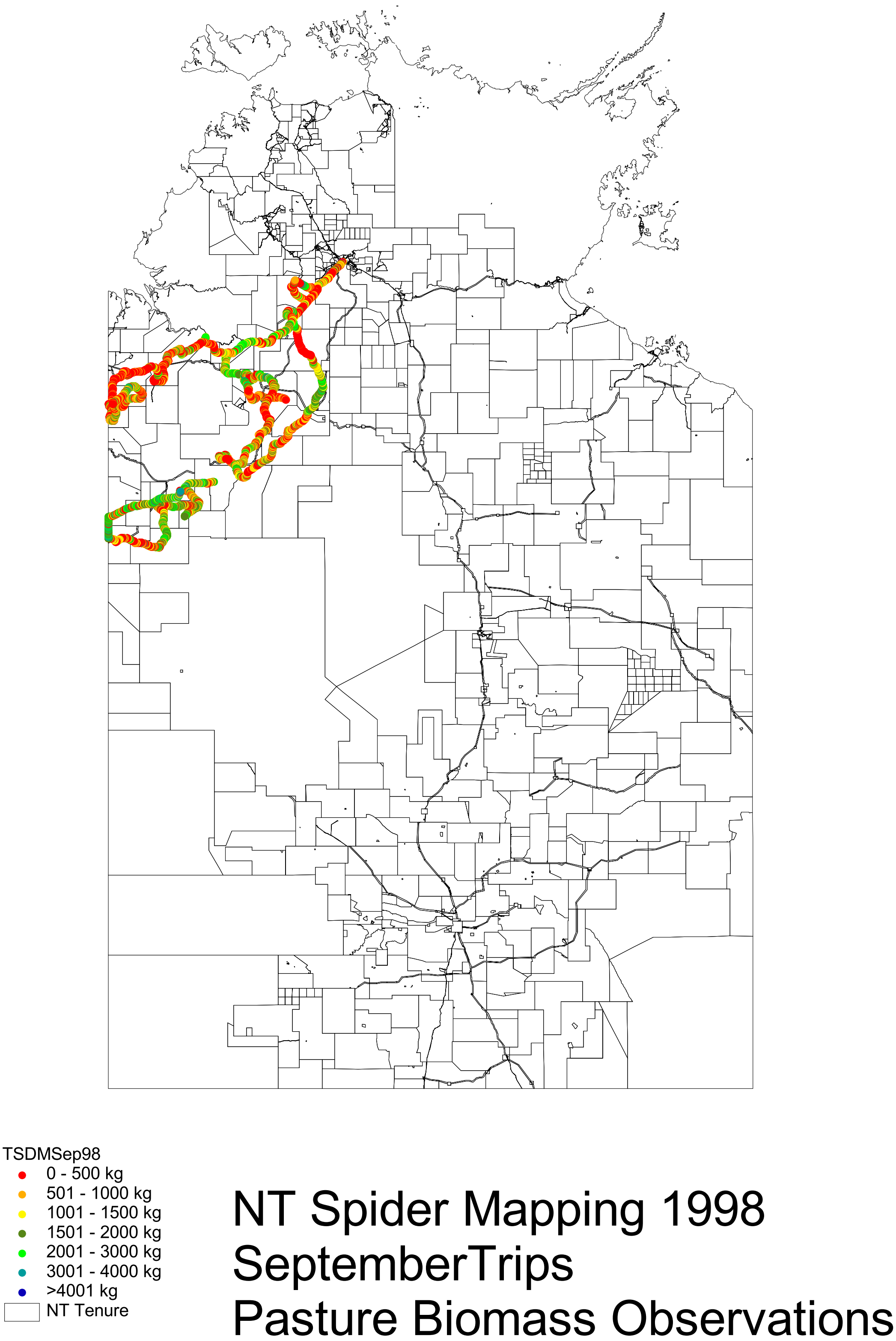


Figure 9. NT spider mapping biomass observations, September 1998.

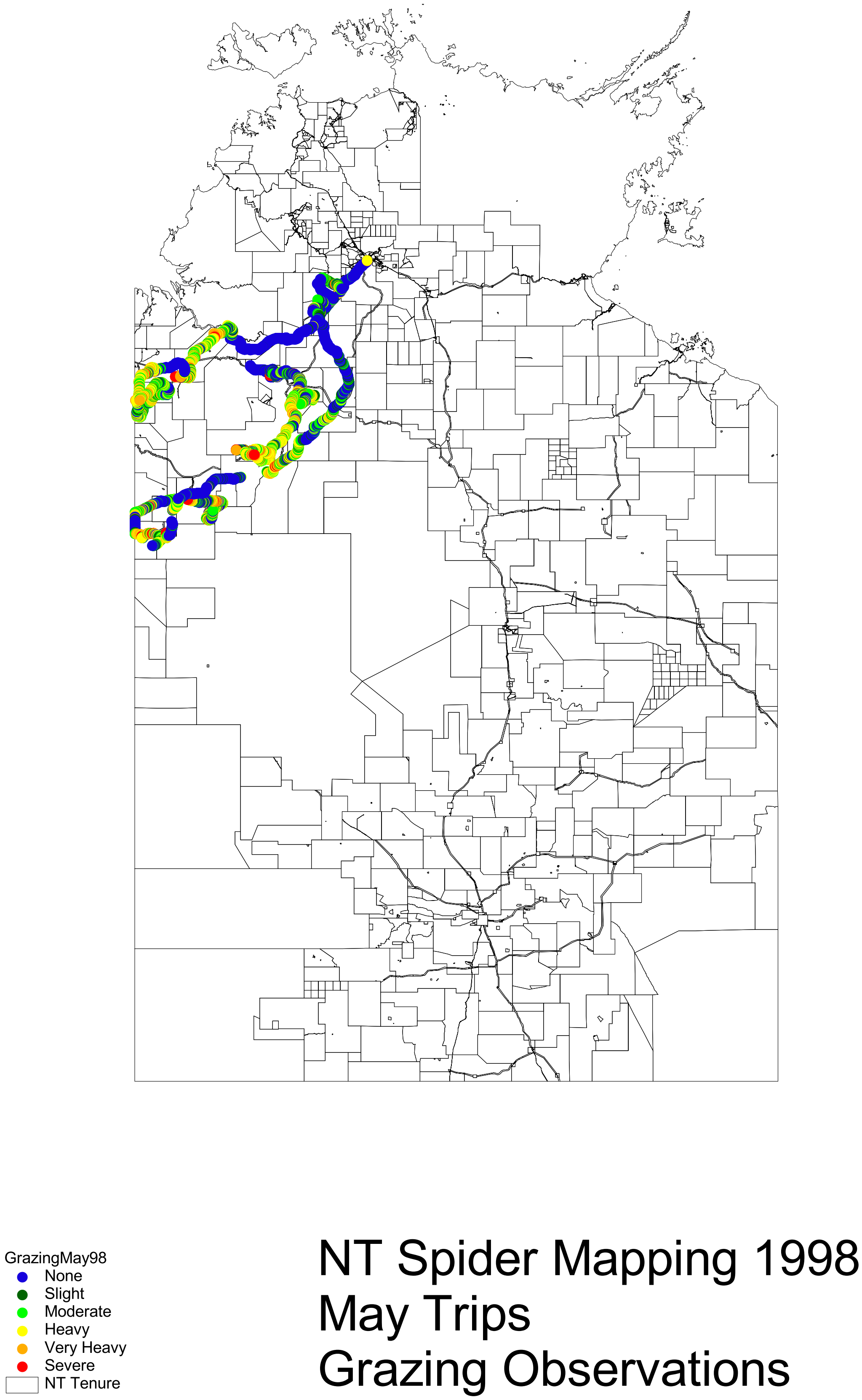


Figure 10. NT spider mapping grazing observations, May 1998.

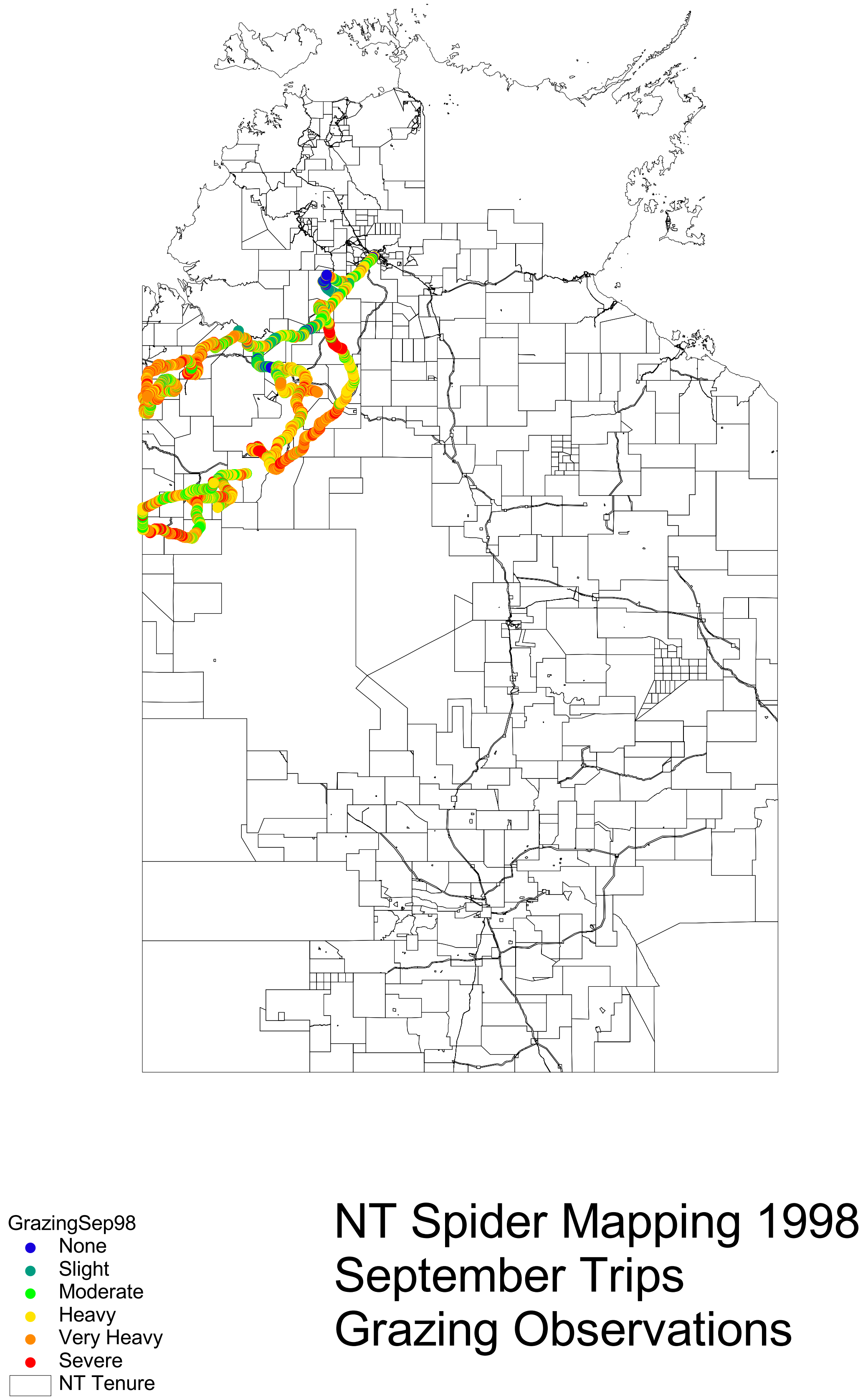


Figure 11. NT spider mapping grazing observations, September 1998.

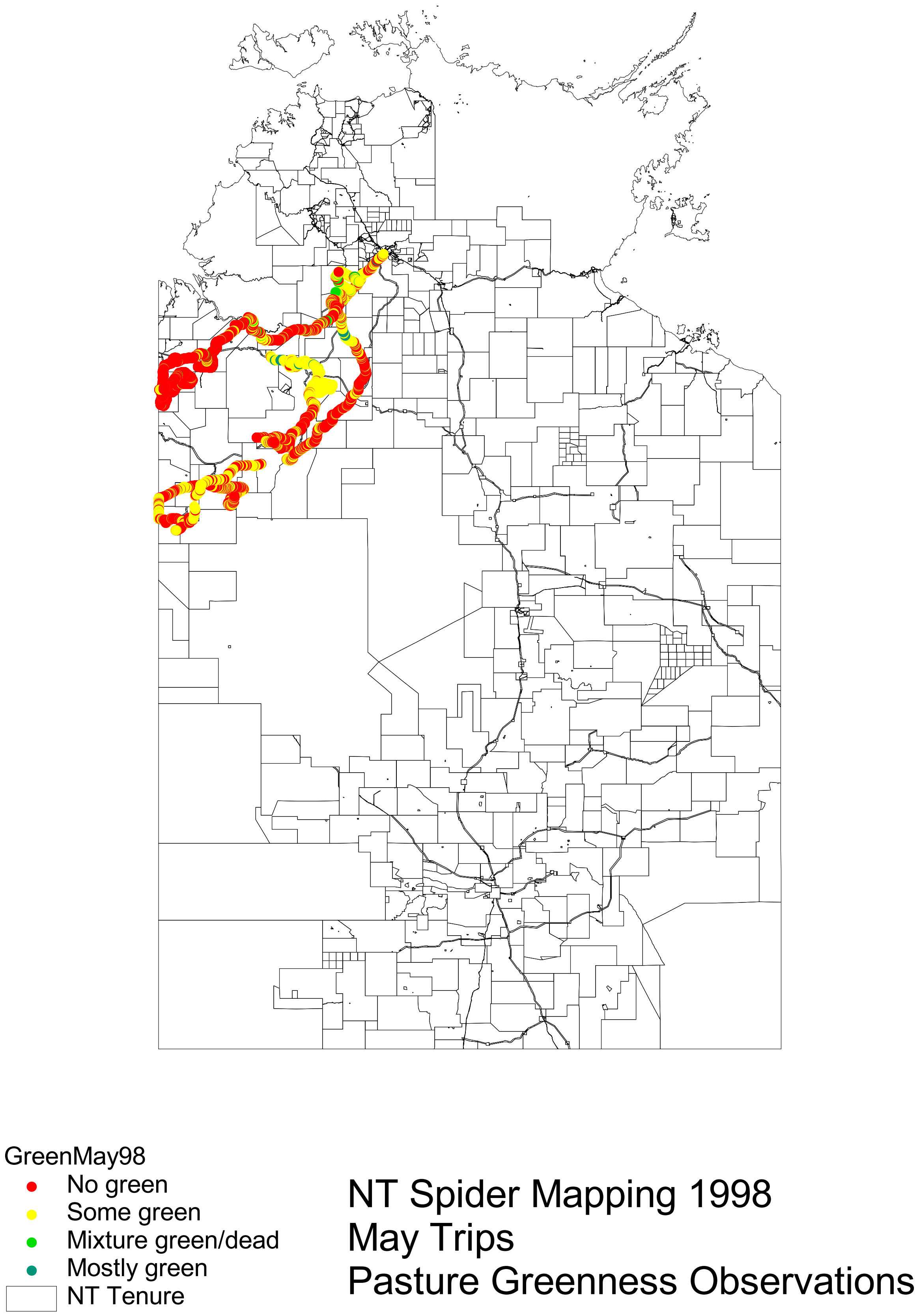


Figure 12. NT spider mapping pasture greenness observations, May 1998.

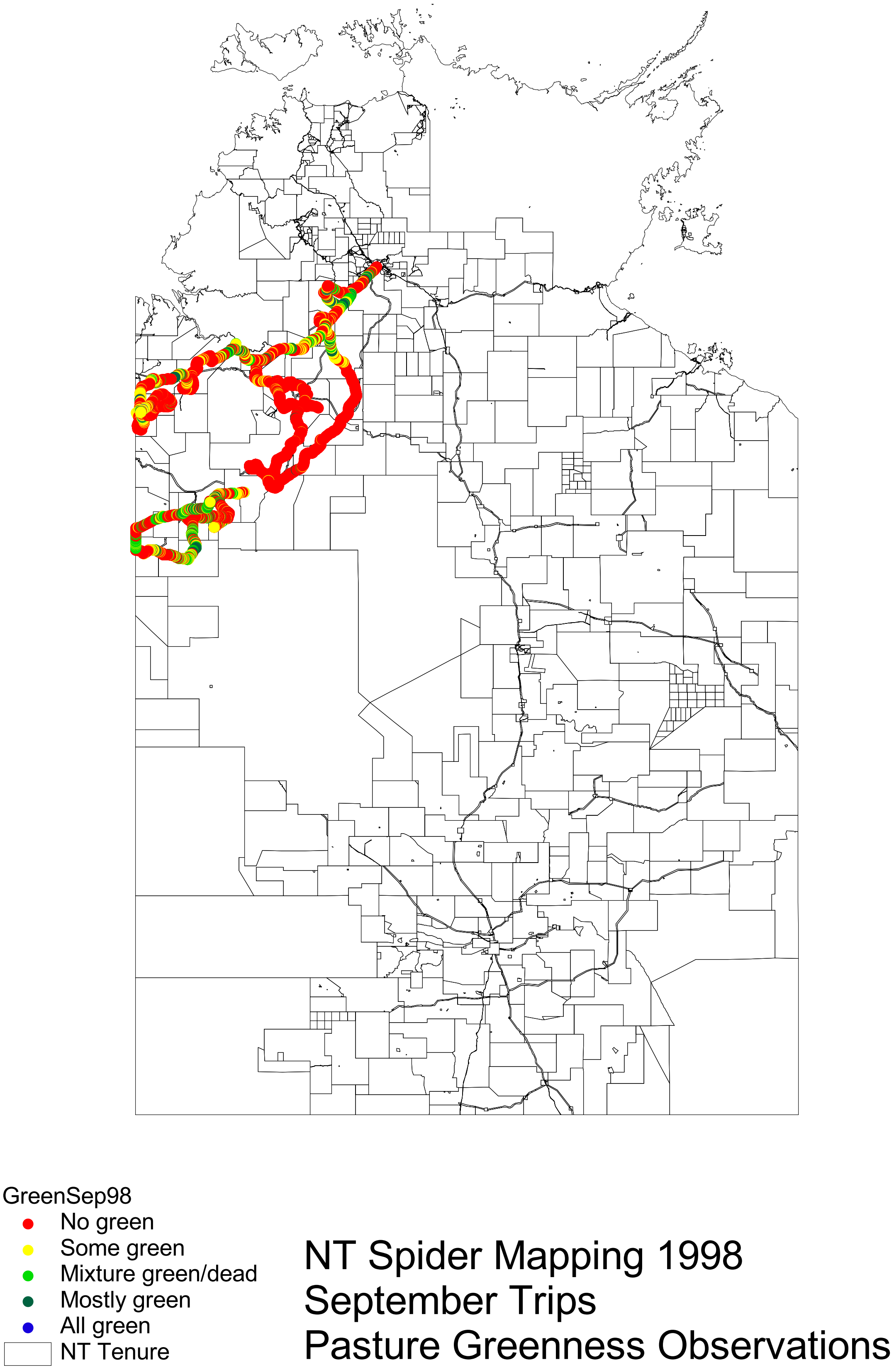


Figure 13. NT spider mapping pasture greenness observations, September 1998.

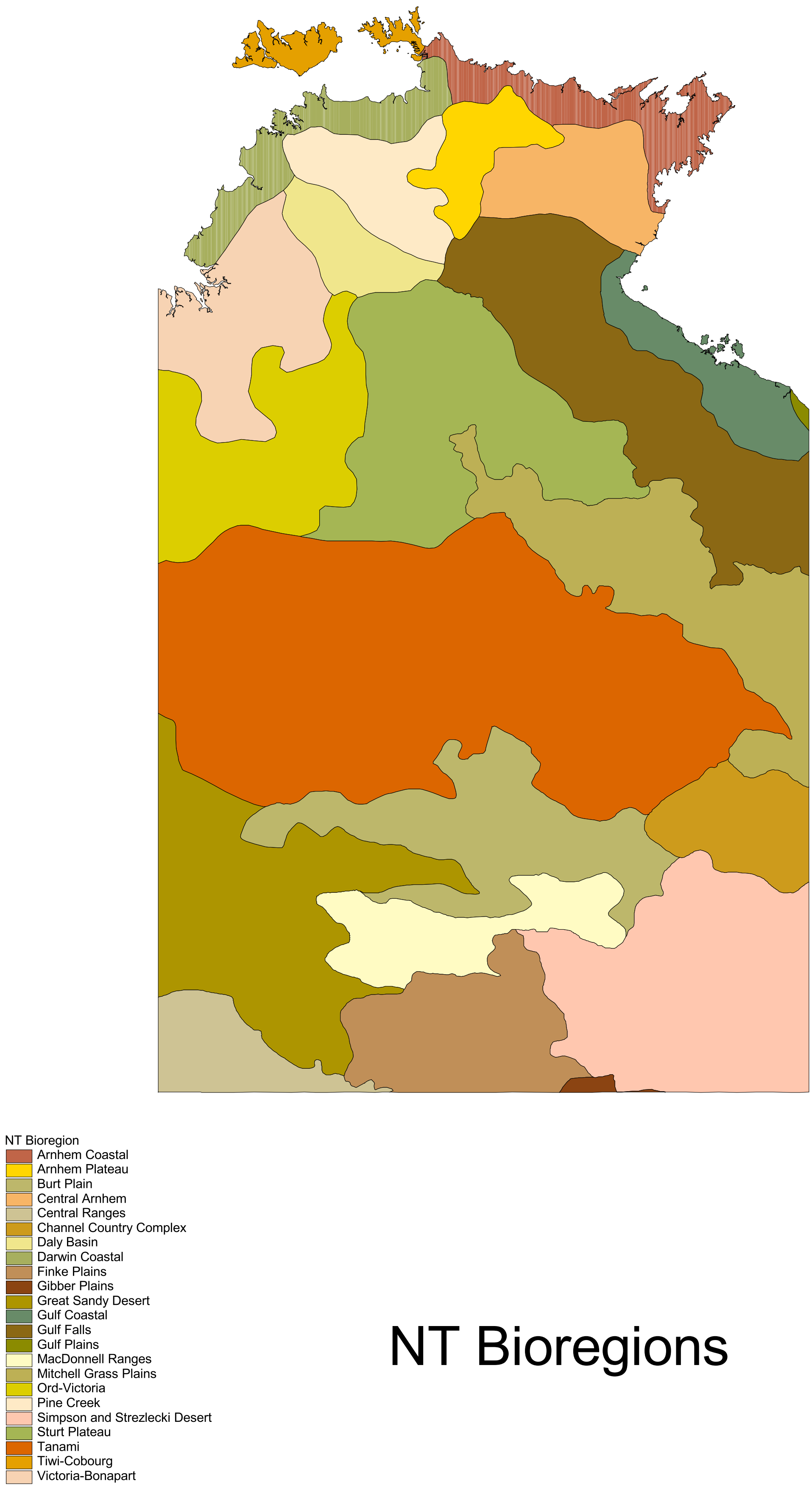


Figure 14. NT bioregions.

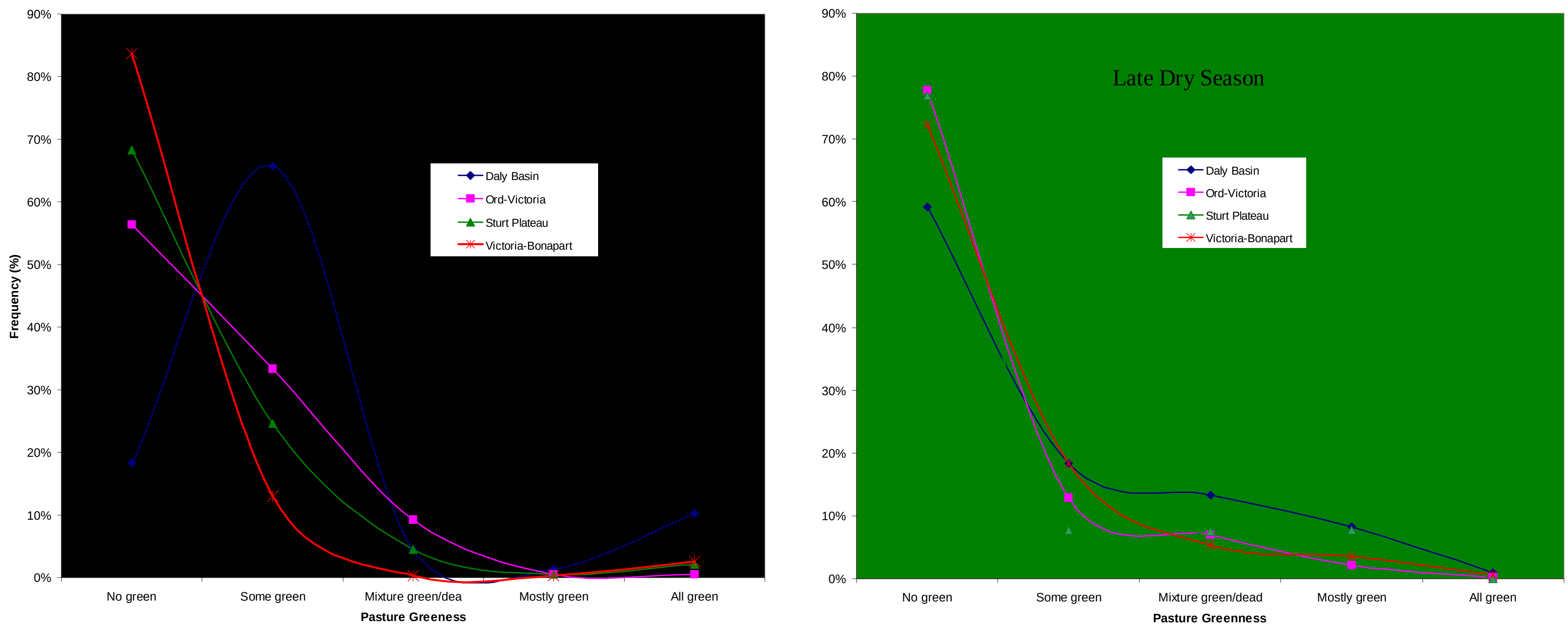


Figure 15. The distribution of pasture greenness classes in the early and late dry season for VRD bioregions in 1998.

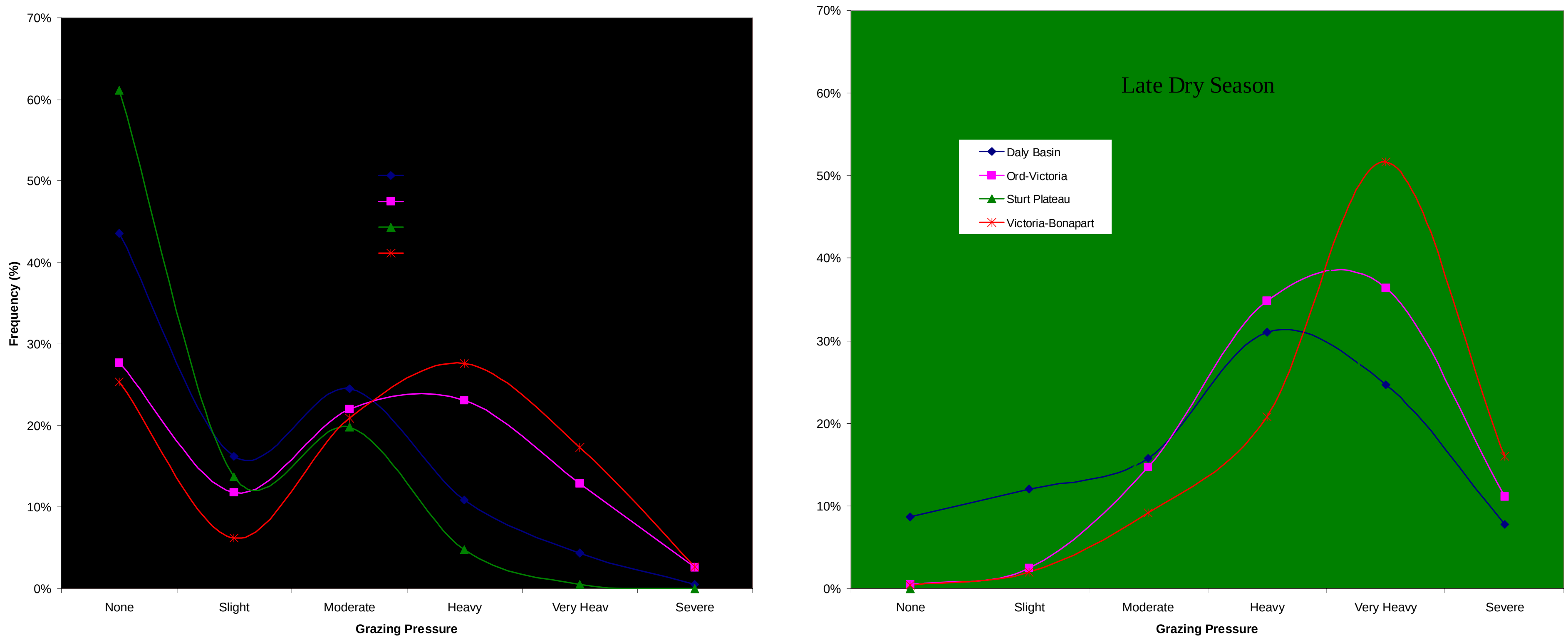
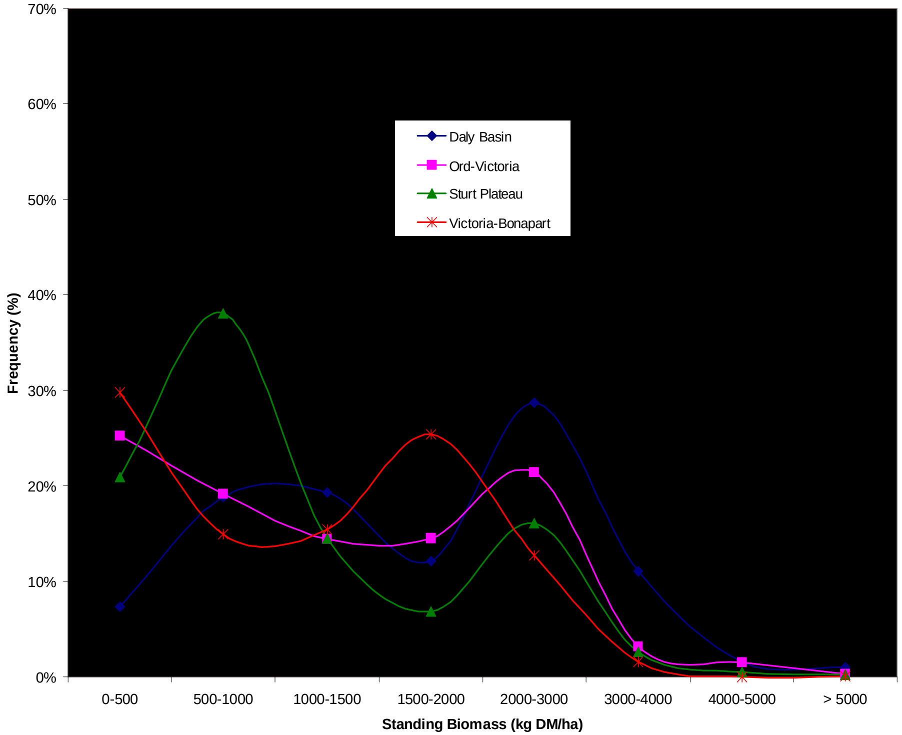


Figure 16. The distribution of grazing pressure classes in the early and late dry season for VRD bioregions in 1998.



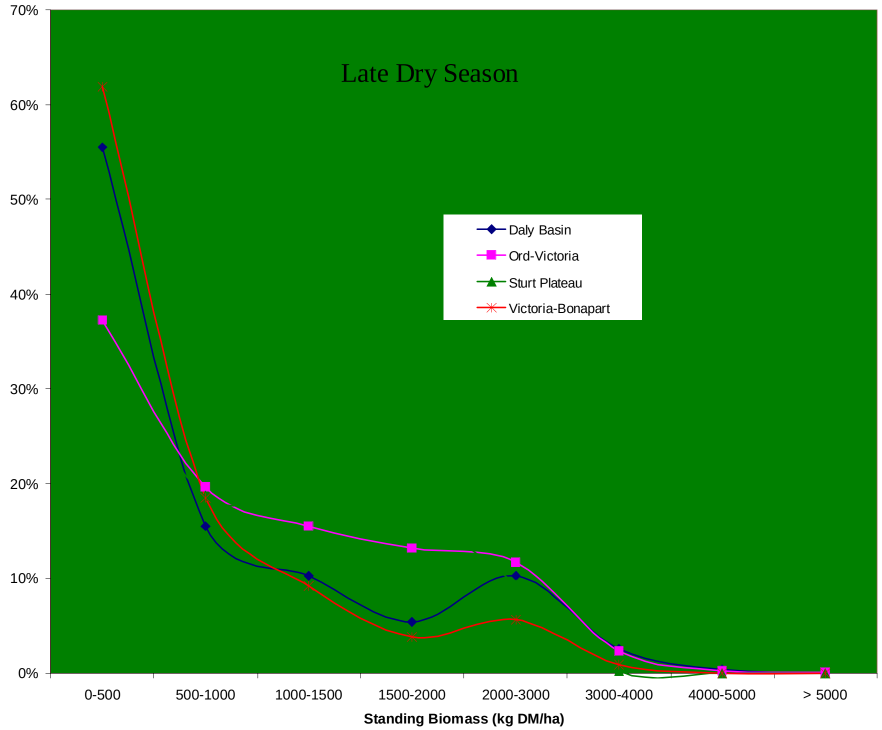


Figure 17. The distribution of standing biomass classes in the early and late dry season for VRD bioregions in 1998.

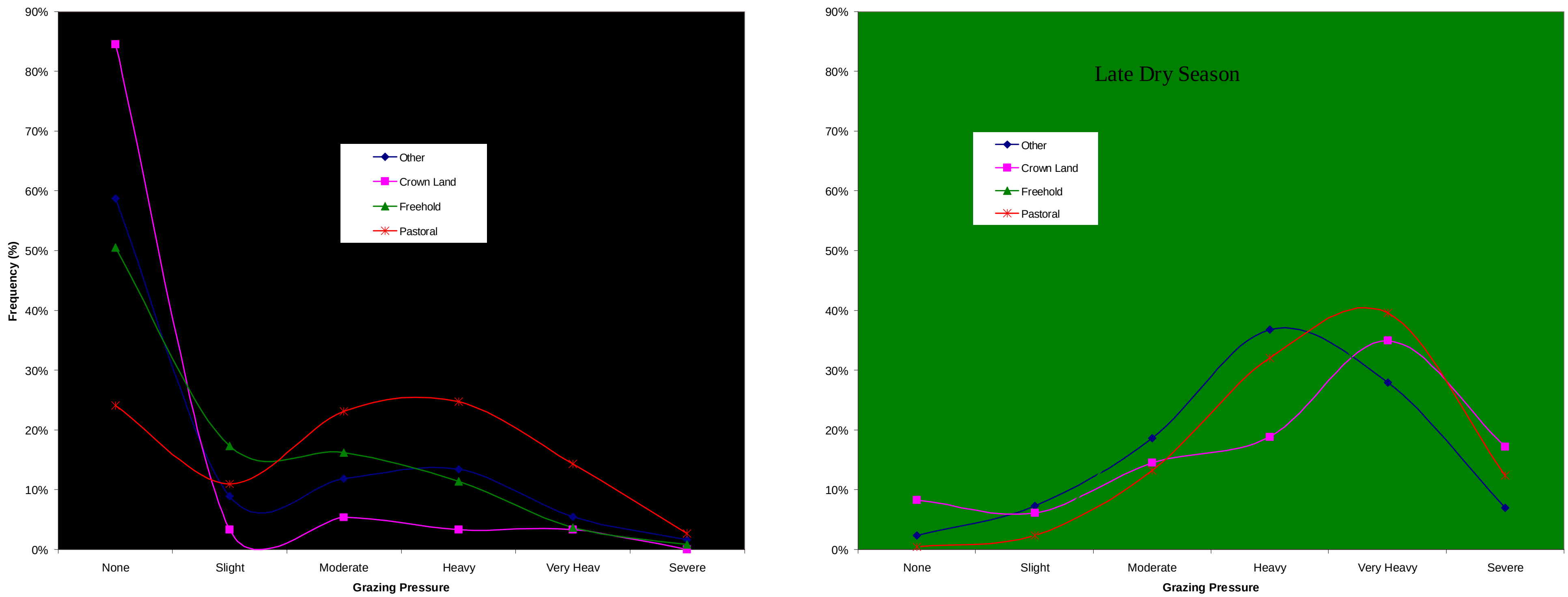


Figure 18. The distribution of grazing pressure classes in the early and late dry season for VRD tenures in 1998.

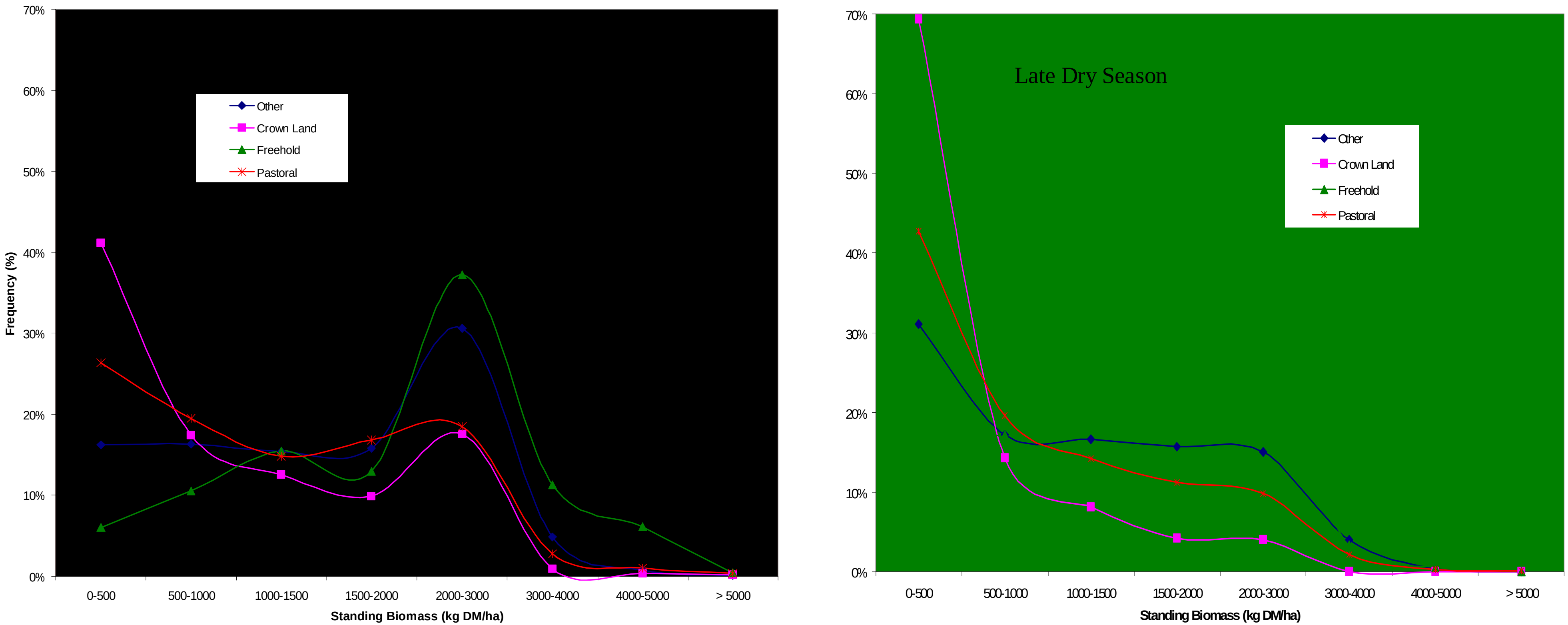


Figure 19. The distribution of standing biomass classes in the early and late dry season for VRD land tenures in 1998.

5.3.1.2 NT - 1999

The field sampling route and observations of standing biomass, grazing pressure and pasture greenness for the NT in 1999 are shown in Figures 20-22. Biomass data were collected from 70% (75) of the 107 vegetation map units described for the NT (Wilson *et al*. 1990). Most major vegetation structure classifications were represented in the field survey (Table 5). The majority of observations were made in eucalypt woodlands, the dominant vegetation type. Significant variations in yield occurred between vegetation types, mainly as a result of seasonal rainfall and grazing pressure. Average yields were greatest in closed grassland, situated mainly in the wet tropics, while yields in grassland communities, mainly Mitchell grass, were the lowest.

Table 5. Average standing biomass (TSDM; kg DM/ha) and number of field observations in major vegetation structure types throughout the NT.

Vegetation structure	TSDM (kg DM/ha)	Observations
Closed forest	1536	6
Closed-grassland	2458	62
Grassland	1094	2097
Low open-shrubland	1138	61
Low open-woodland	1427	2449
Low woodland	1241	3325
Open-forest	1603	2694
Shrubland	1510	2239
Woodland	1506	7180

The distributions of standing biomass and grazing pressure for land tenures throughout the NT in 1999 are shown in Figures 23 and 24. In general all yield classes up to 3,000 kg DM/ha were well represented, with less than 10% of total observations exceeding 3,000 kg DM/ha. A trend towards heavier grazing pressure on pastoral land was clear and expected. At least 50% of grazing pressure observations were moderate or lower.

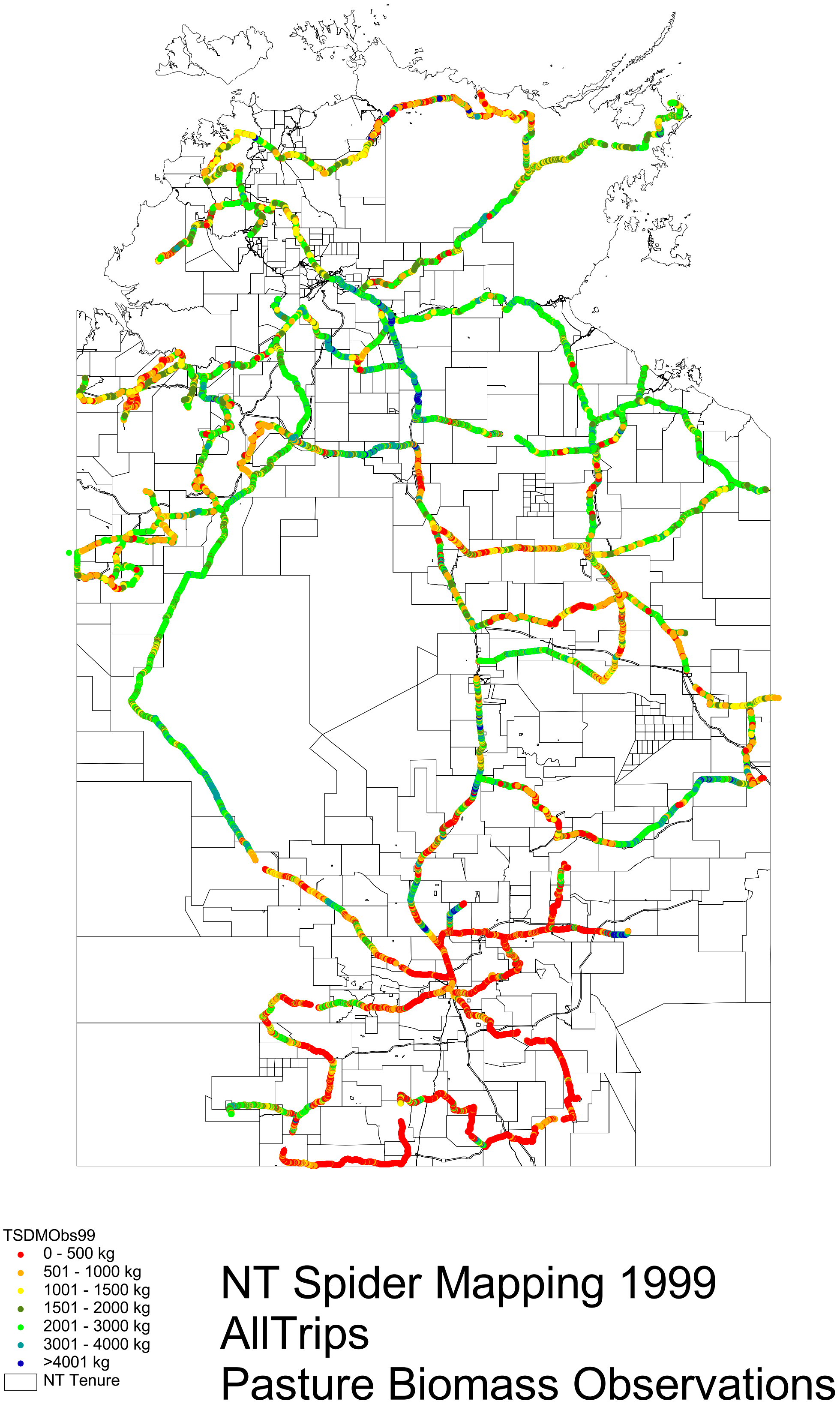


Figure 20. NT spider mapping biomass observations, 1999.

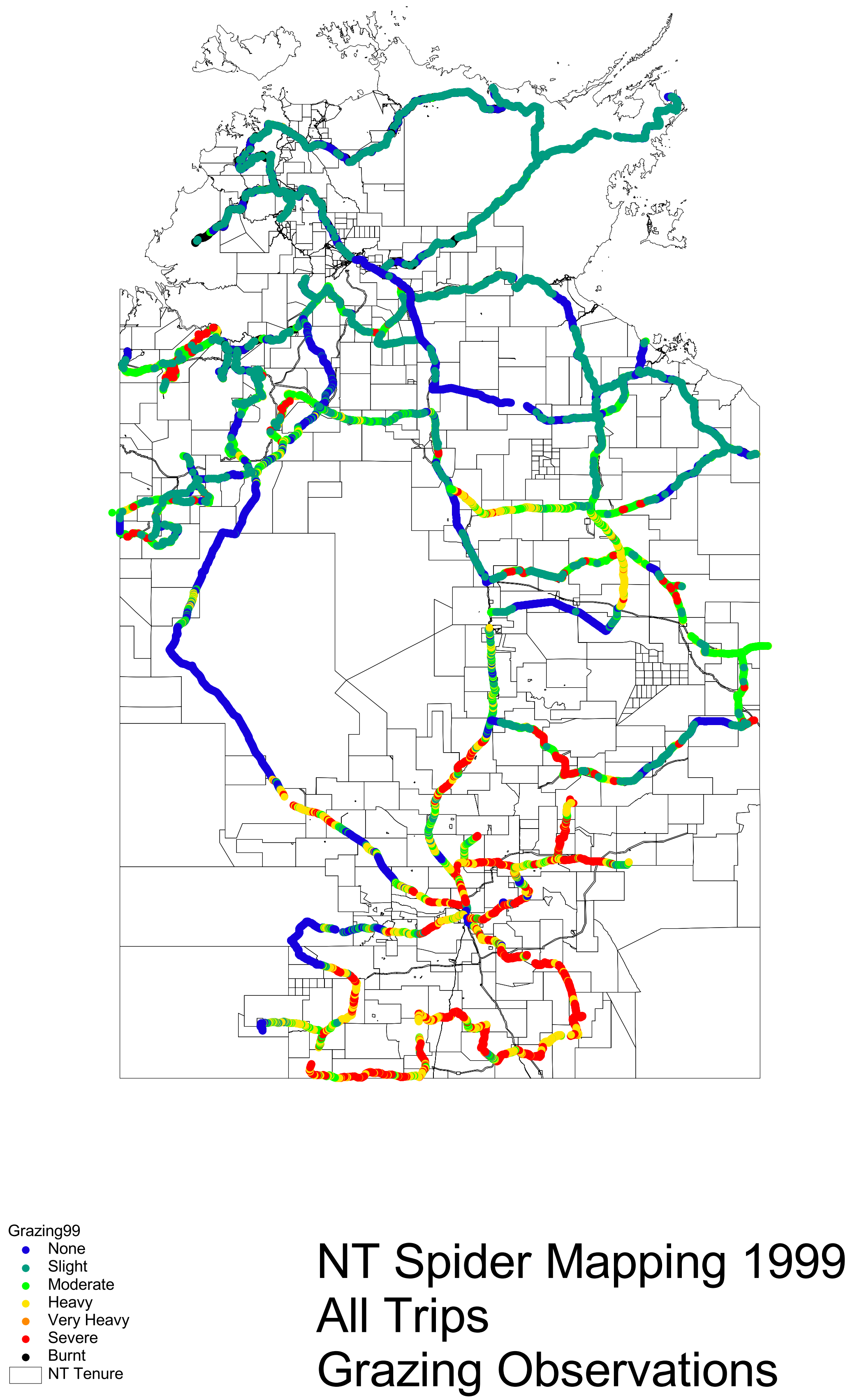


Figure 21. NT spider mapping grazing observations, 1999.

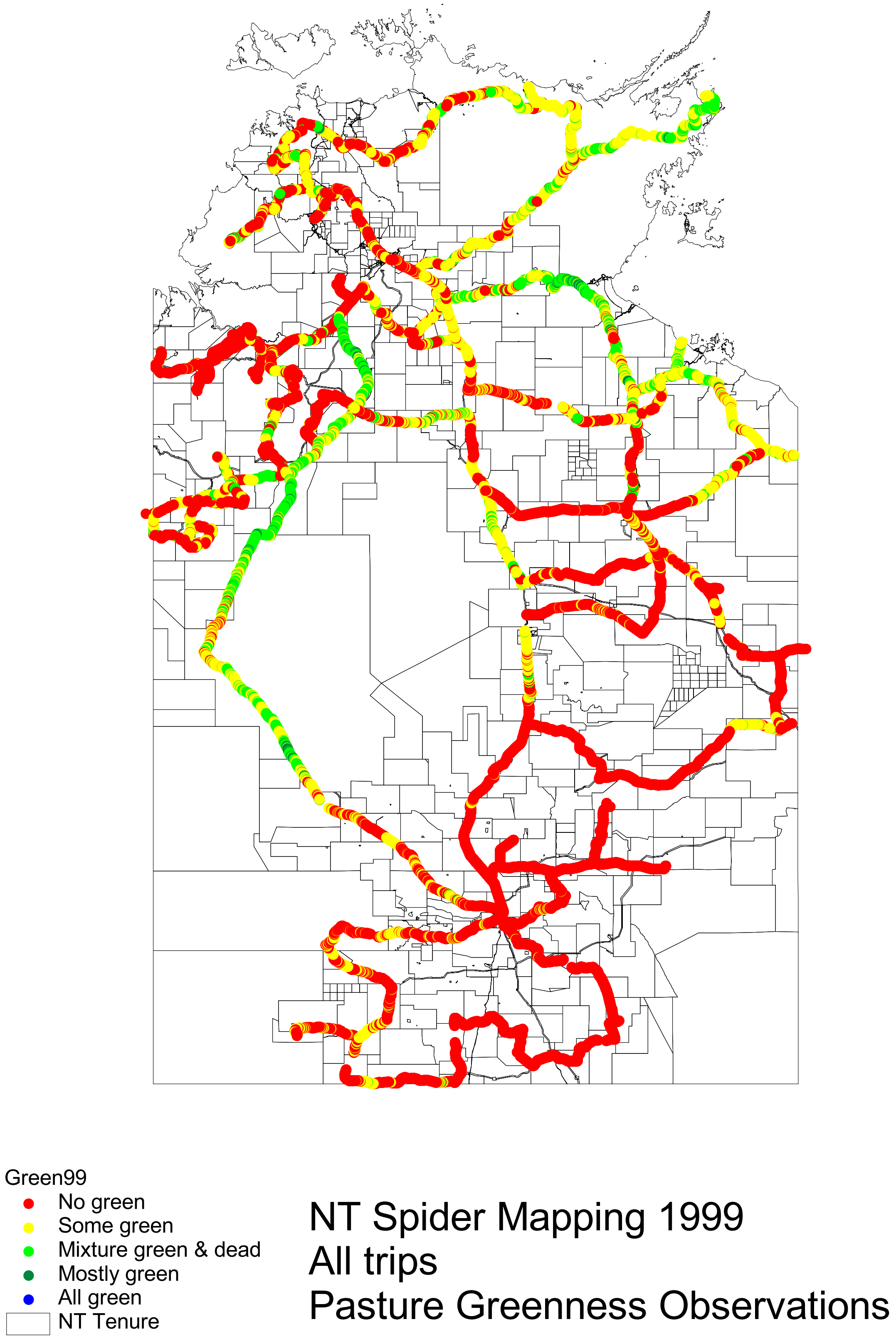


Figure 22. NT spider mapping pasture greenness observations, 1999.

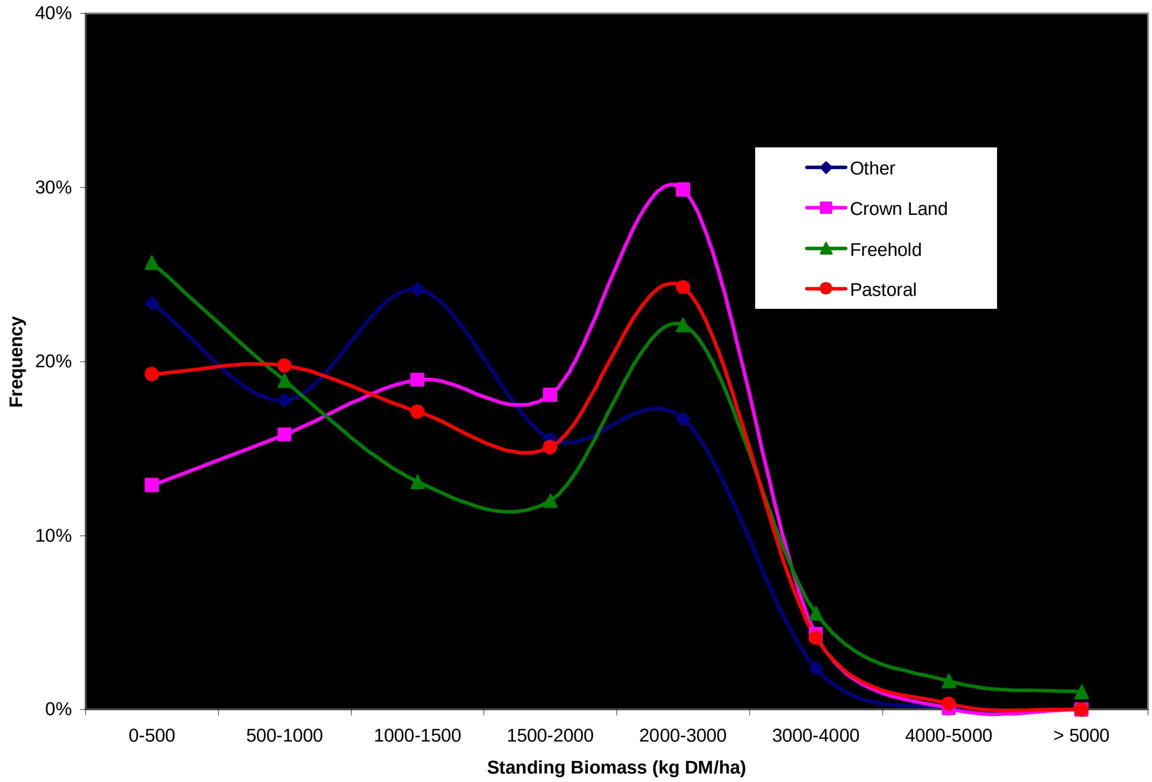


Figure 23. The distribution of standing biomass classes for NT land tenures in 1999.

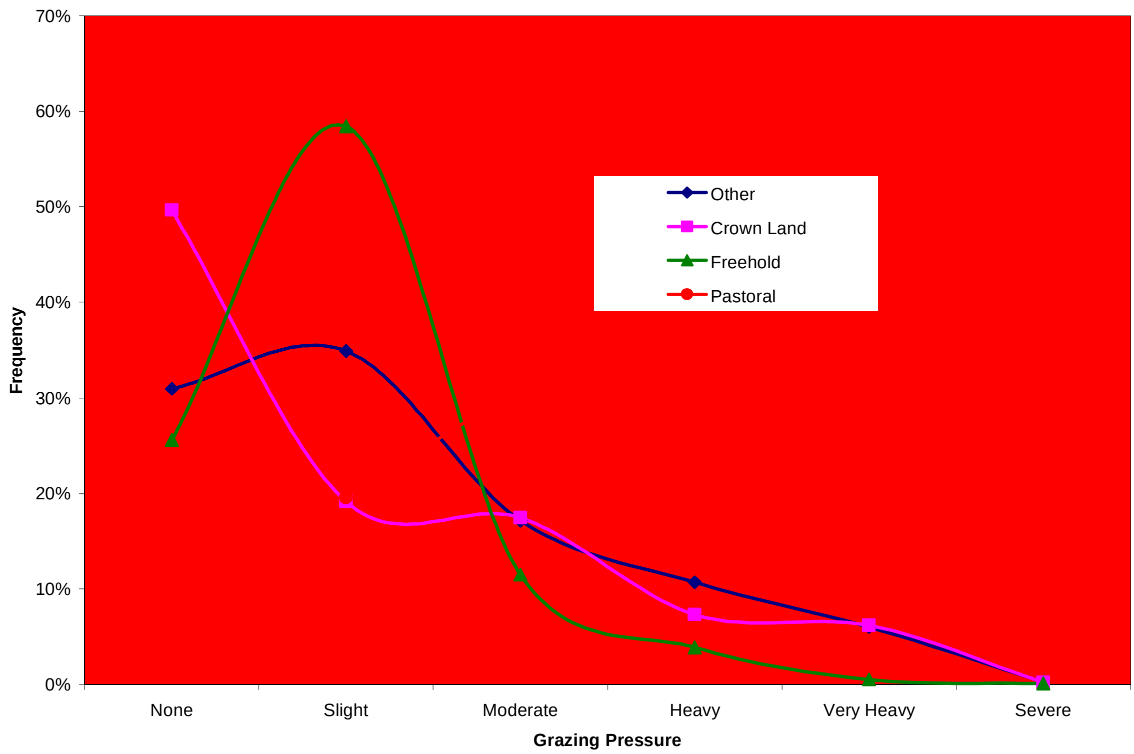


Figure 24. The distribution of grazing pressure classes for NT land tenures in 1999.

All major bioregions throughout the NT were sampled. A summary of average standing biomass, standard error and the number of observations for each bioregion is shown in Table 6. Considerable variation in standing biomass and grazing pressure distribution existed between bioregions (Table 6 and Figures 25 and 26). Low standing biomass and high grazing pressure were apparent throughout the central Australian bioregions such as Burt Plain, Central Ranges, Finke Plains, Great Sandy Desert and MacDonnell Ranges. In these regions over 60% of biomass observations were less than 500 kg DM/ha,

Over 50% of grazing pressure observations were classified as very heavy or severe. High standing biomass and low grazing pressure were characteristic of the Sturt Plateau and the Gulf Falls compared to other more intensively developed pastoral areas. Grazing pressure throughout the Arnhem bioregions was very low (80% slight or none) reflecting the low density of pastoral enterprises throughout this area.

Table 6. Average standing biomass (TSDM: kg DM/ha), observations (n) and mean standard error (SEM) measured for NT bioregions in 1999.

Bioregion	TSDM	n	SEM
Arnhem Coastal	1204	2323	24
Arnhem Plateau	1486	201	159
Central Arnhem	1792	1292	29
Daly Basin	1392	919	32
Darwin Coastal	1158	362	42
Gulf Coastal	2114	232	41
Gulf Falls	1715	1208	26
Ord-Victoria (late dry)	1617	3864	14
Ord-Victoria (early dry)	1963	1045	23
Pine Creek	1039	1960	16
Sturt Plateau	1791	1166	28
Victoria-Bonaparte	1104	2841	14
Burt Plain	810	3146	18
Central Ranges	449	224	20
Finke Plains	529	2531	16
Great Sandy Desert	1434	674	36
MacDonnell Ranges	654	2560	14
Simpson and Strezlecki Desert	410	1663	19
Tanami	2288	2336	19
Summary	**1313**	**30547**	**31**

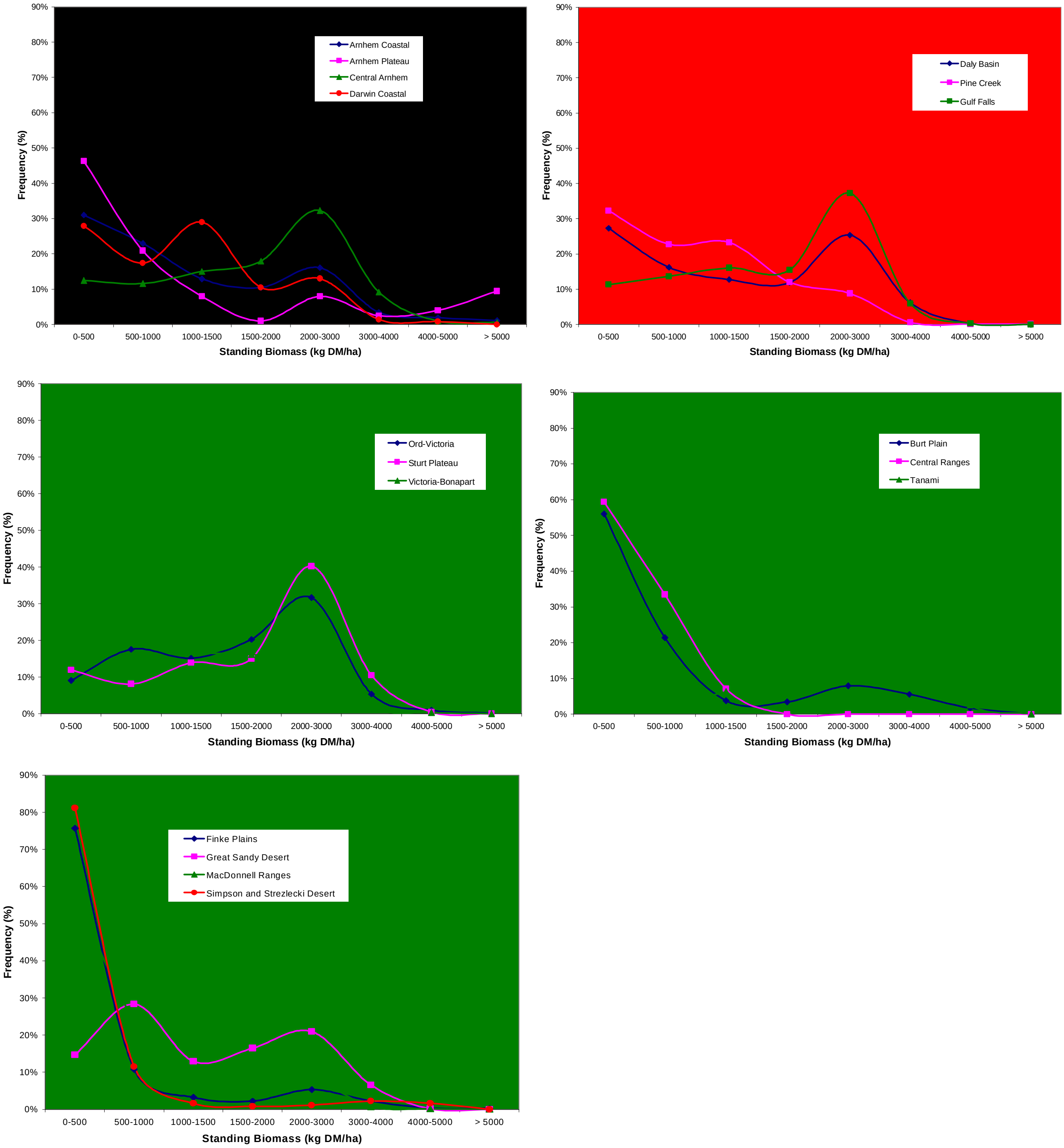


Figure 25. The distribution of standing biomass classes for NT bioregions in 1999.

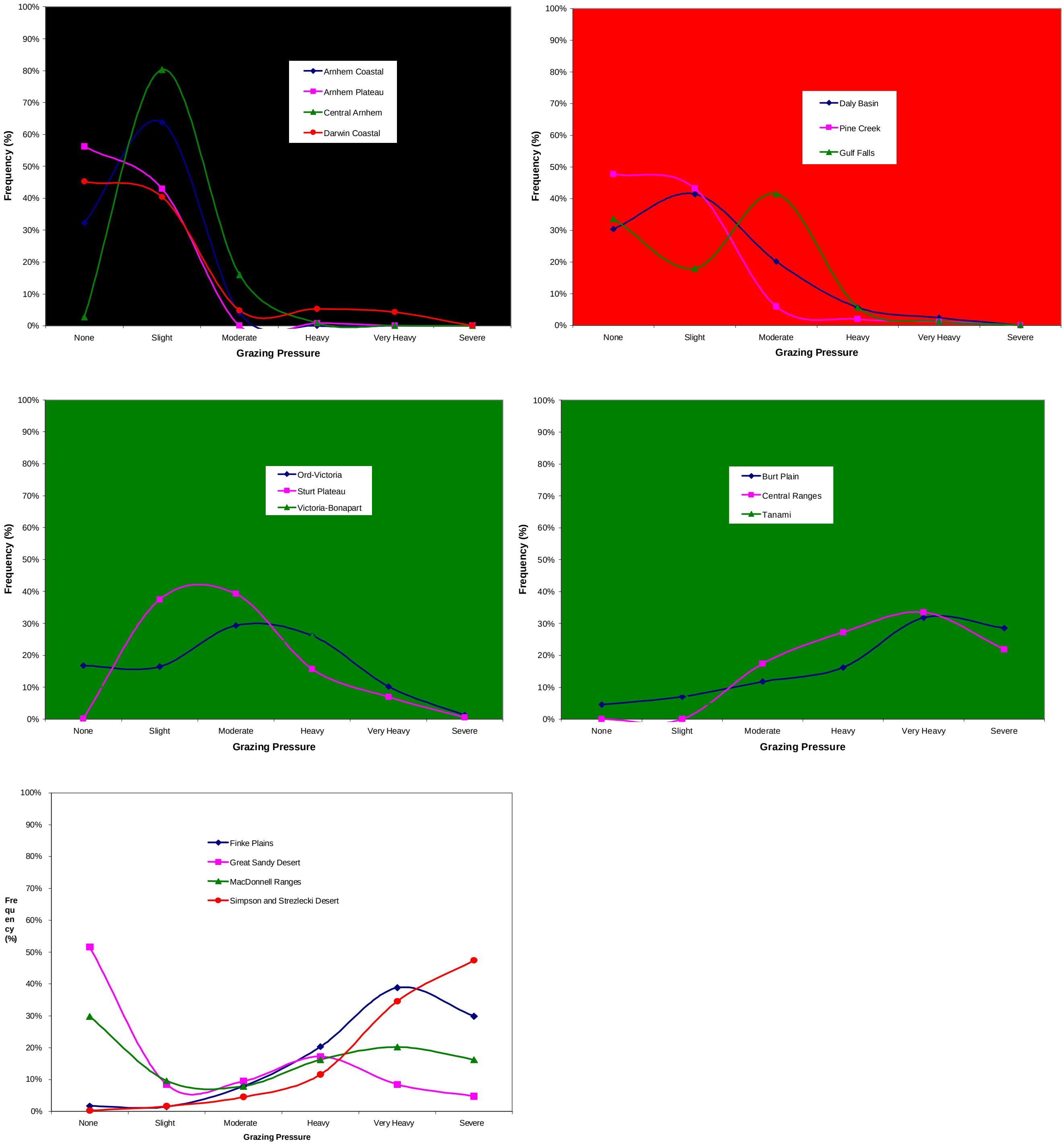


Figure 26. The distribution of grazing pressure classes for NT bioregions in 1999.

5.3.2 Kimberley, Western Australia

Spider mapping trips were carried out in the Kimberley region of northern Western Australia in 1998 and 1999. In 1998 trips concentrated on the eastern Kimberley area. In 1999 both the eastern and western Kimberley were covered with the aim of covering as many pasture communities (Figure 27), bioregions (Figure 28), and vegetation classifications (Figure 29) as possible. Details of the 1998 and 1999 trips are shown in Table 7. The locations of all Kimberley calibration sites are shown in Figure 6.

Table 7. Details of the spatial validation trips carried out in the Kimberley region of Western Australia in 1998 and 1999.

Year	Trip	No of obs	Days per correlation	Duration of trip	Observer	Mean r^2	No of sites
1998	1	2583	2.0	1-6 June	MB	0.817	23
					SO	0.813	23
	2	4227	1.0	26-30 October	MB	0.874	47
					SO	0.840	47
1999	3	4244	1.1	14-22 June	SO	0.859	64
					SM	0.876	64
	4	6010	1.0	15-23 June	MB	0.928	67
					TD	0.917	67
	5	1749	1.0	20-23 July	SO	0.840	33
					SM	0.843	33
	6	6212	1.0	20-29 July	MB	0.960	65
					TD	0.966	65

5.3.2.1 Kimberley 1998

The sampling route, and classifications of biomass, grazing pressure and pasture greenness for early dry (June) and late dry (October) field surveys are shown in Figures 30-37. The majority of observations were on pastoral land within the Ord Victoria Plains (OVP) bioregion.

Average pasture biomass values for the various bioregions are shown in Table 8. Pasture biomass was highest in the central Kimberley (about 1900 kg DM/ha) and lowest in the Tanami (about 1200 kg DM/ha). There was a reduction in average biomass between early and late dry seasons of about 40% in the OVP and >55% in the Tanami. Pasture biomass distributions were highly skewed (Figure 36). In the case of the OVP, the distribution shows the expected shift to lower biomass classes (e.g. 0-500 kg DM/ha) between the early and late dry season, reflecting the effects of fire, grazing and detachment.

Table 8. Average standing biomass (TSDM; kg DM/ha), observations (n) and mean standard error (SEM) measured for Kimberley bioregions in the early dry season and late dry season, 1998.

Bioregion	Early Dry Season			Late Dry Season		
	TSDM	SEM	n	TSDM	SEM	n
Central Kimberley	1916	404	15	1201	88	321
Ord Victoria Plains	1473	30	2306	864	22	3154
Tanami	1164	112	188	501	47	314
Victoria Bonaparte	-	-	-	522	78	216

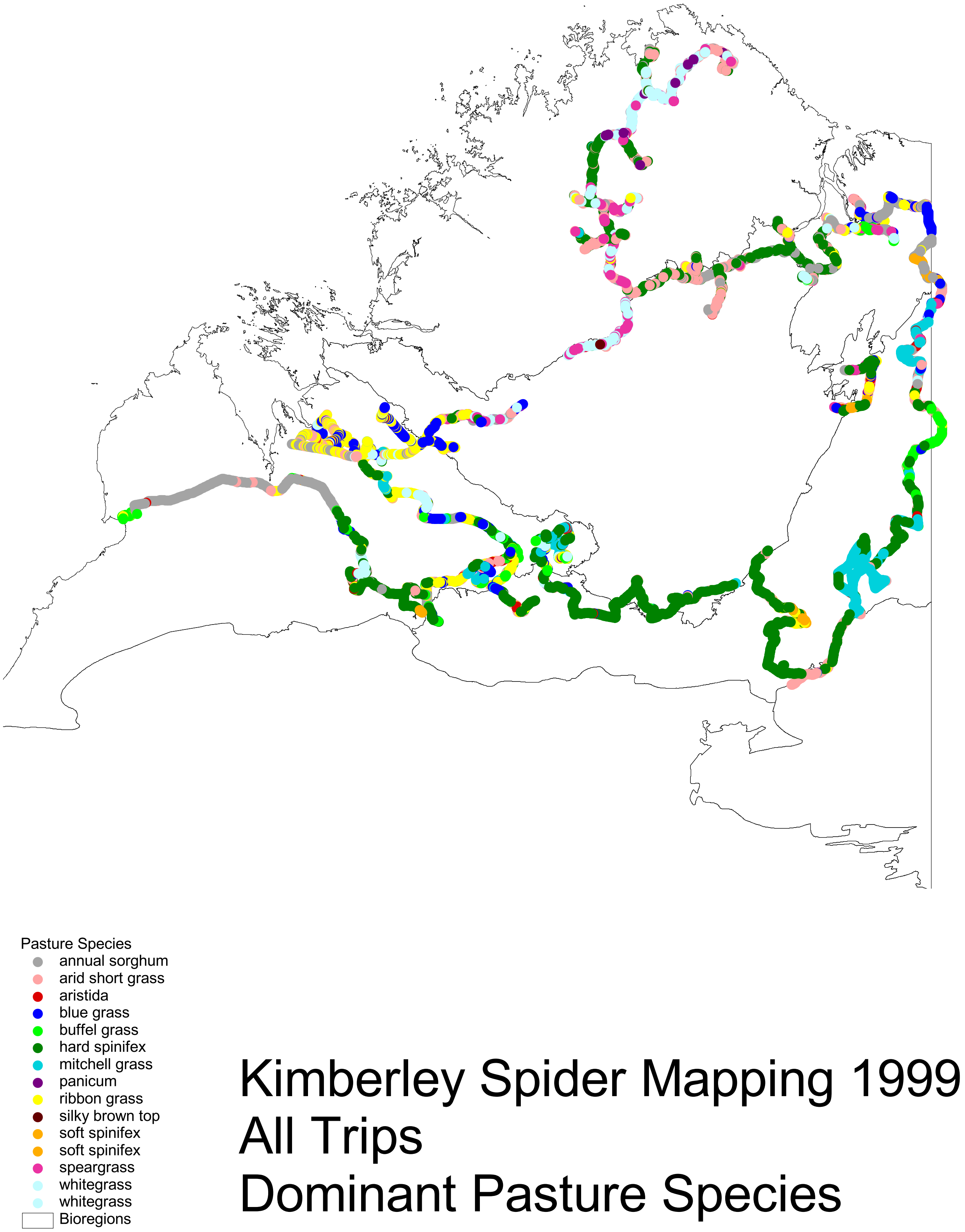


Figure 27. Kimberley spider mapping dominant pasture species observations, 1999.

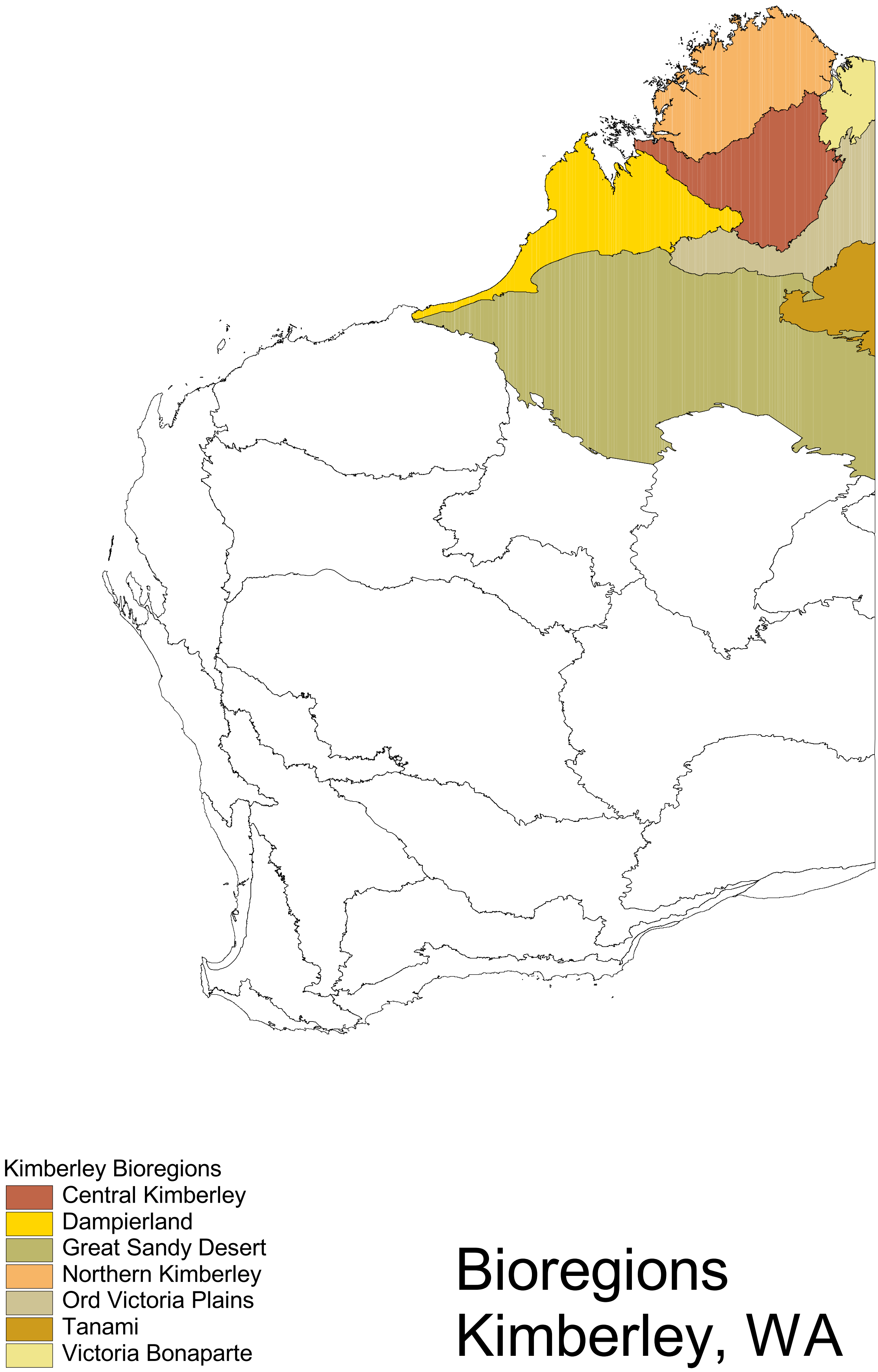
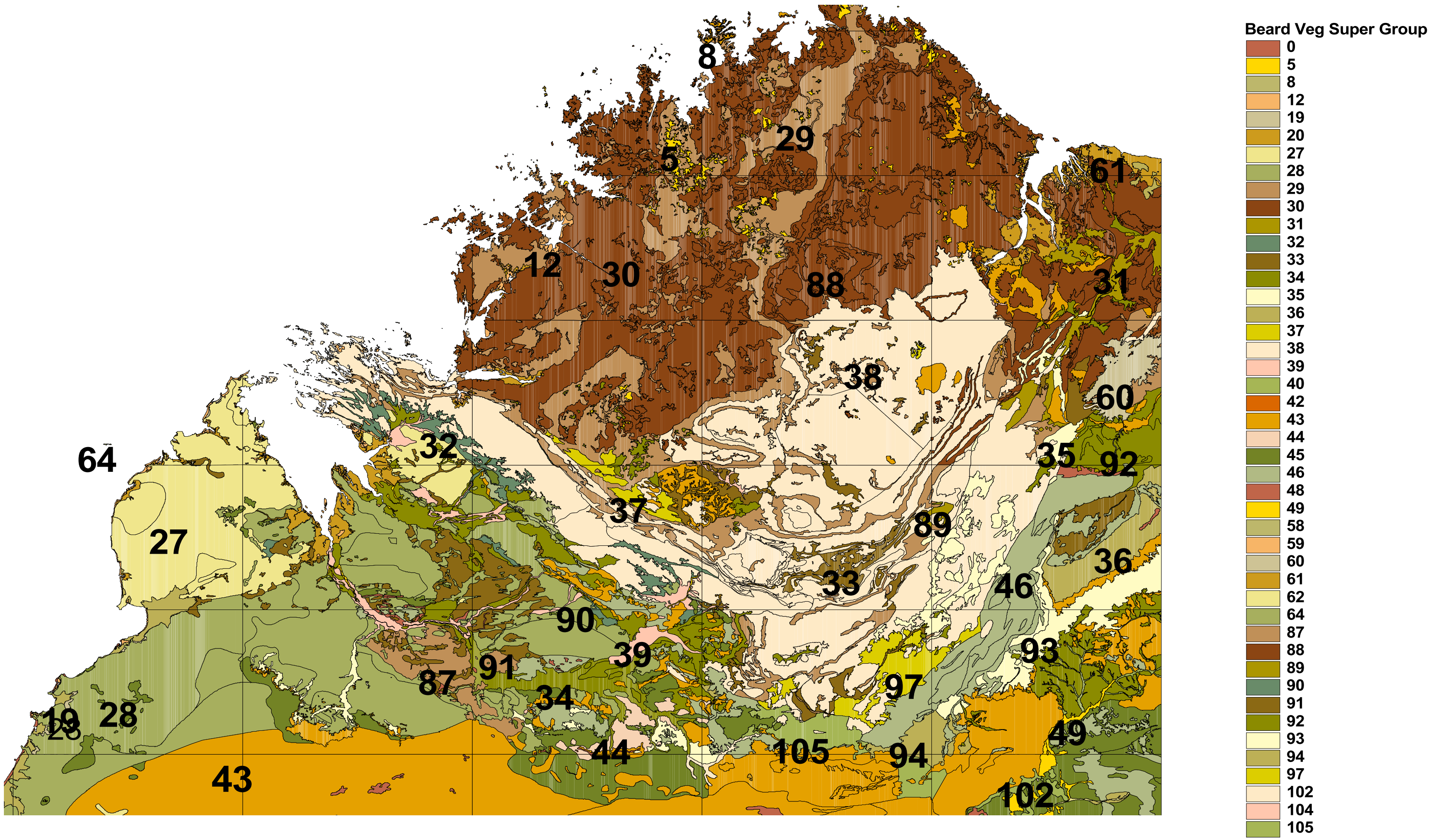


Figure 28. Kimberley bioregions.



Kimberley, WA
Beard Vegetation Super Groups

Figure 29. Kimberley vegetation as mapped by Beard (1979).

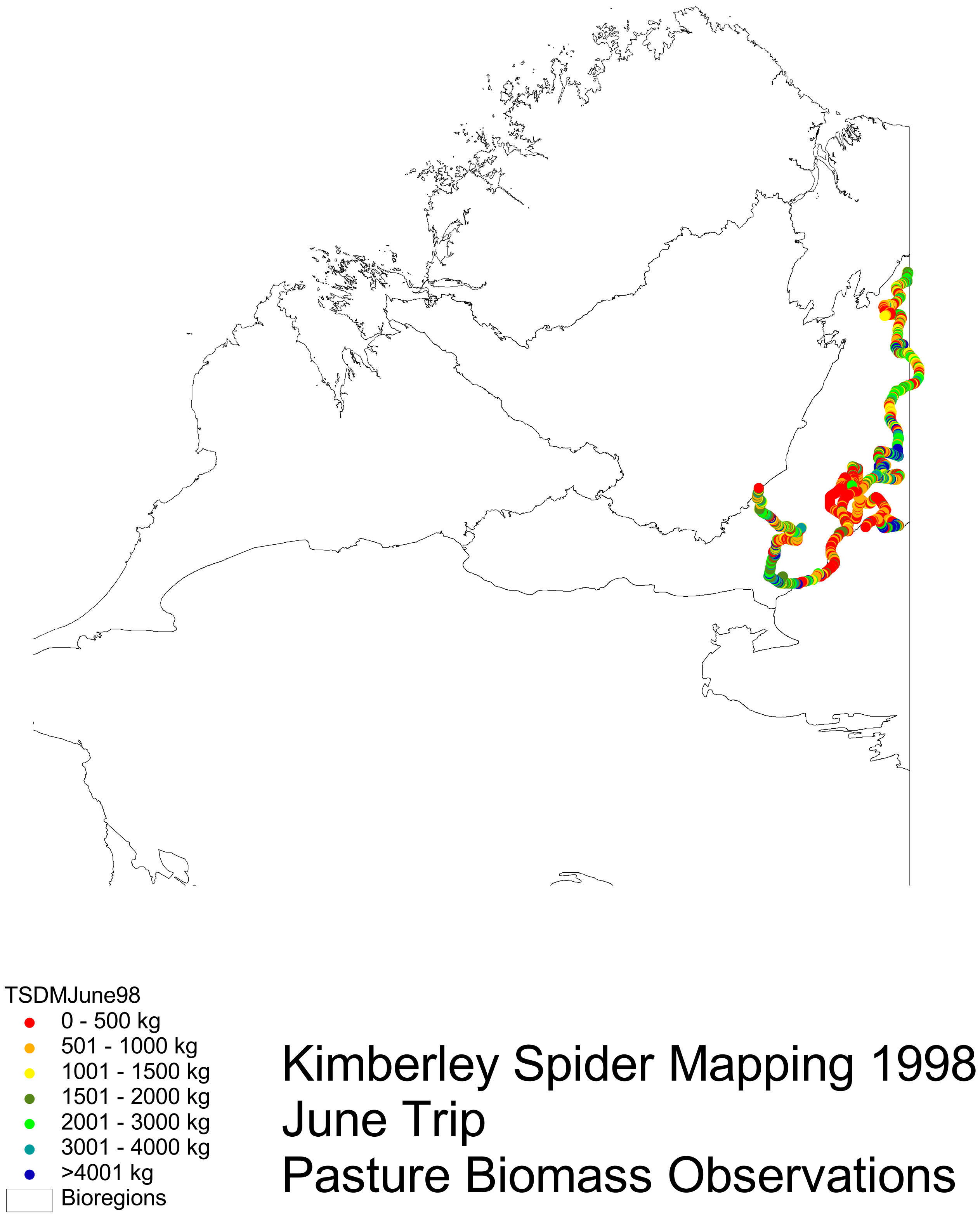


Figure 30. Kimberley spider mapping biomass observations, June 1998.

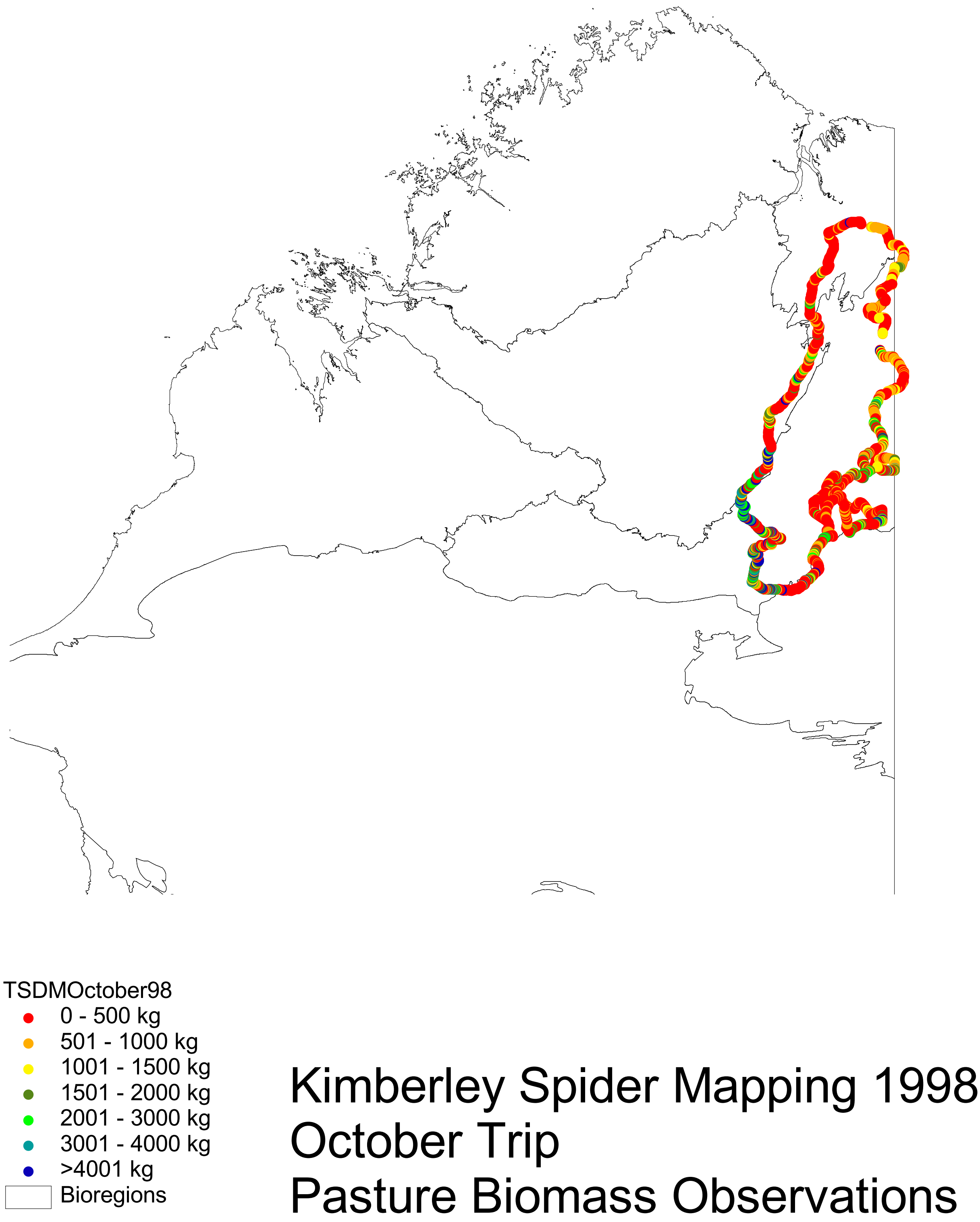


Figure 31. Kimberley spider mapping biomass observations, October 1998.

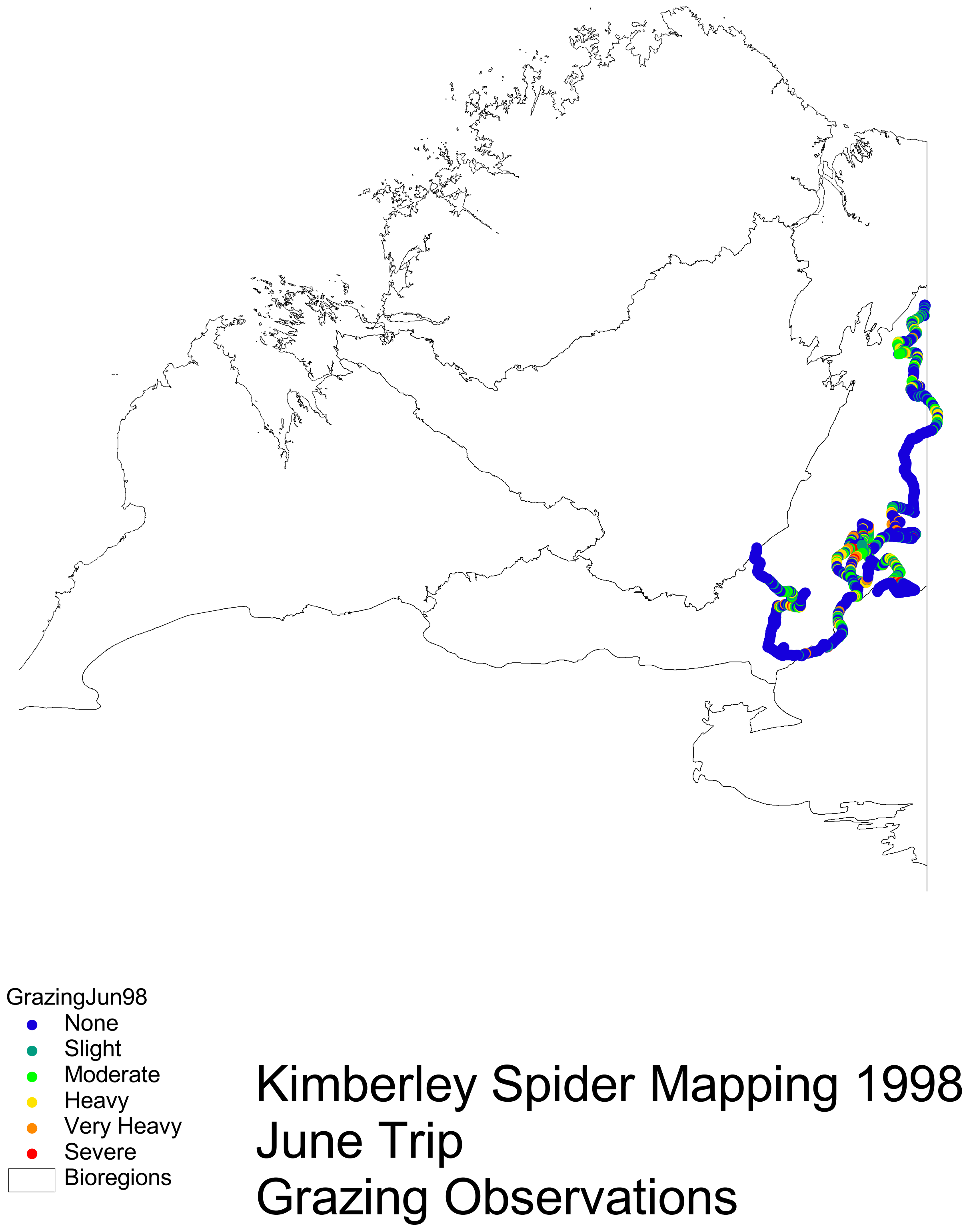


Figure 32. Kimberley spider mapping grazing observations, June 1998.

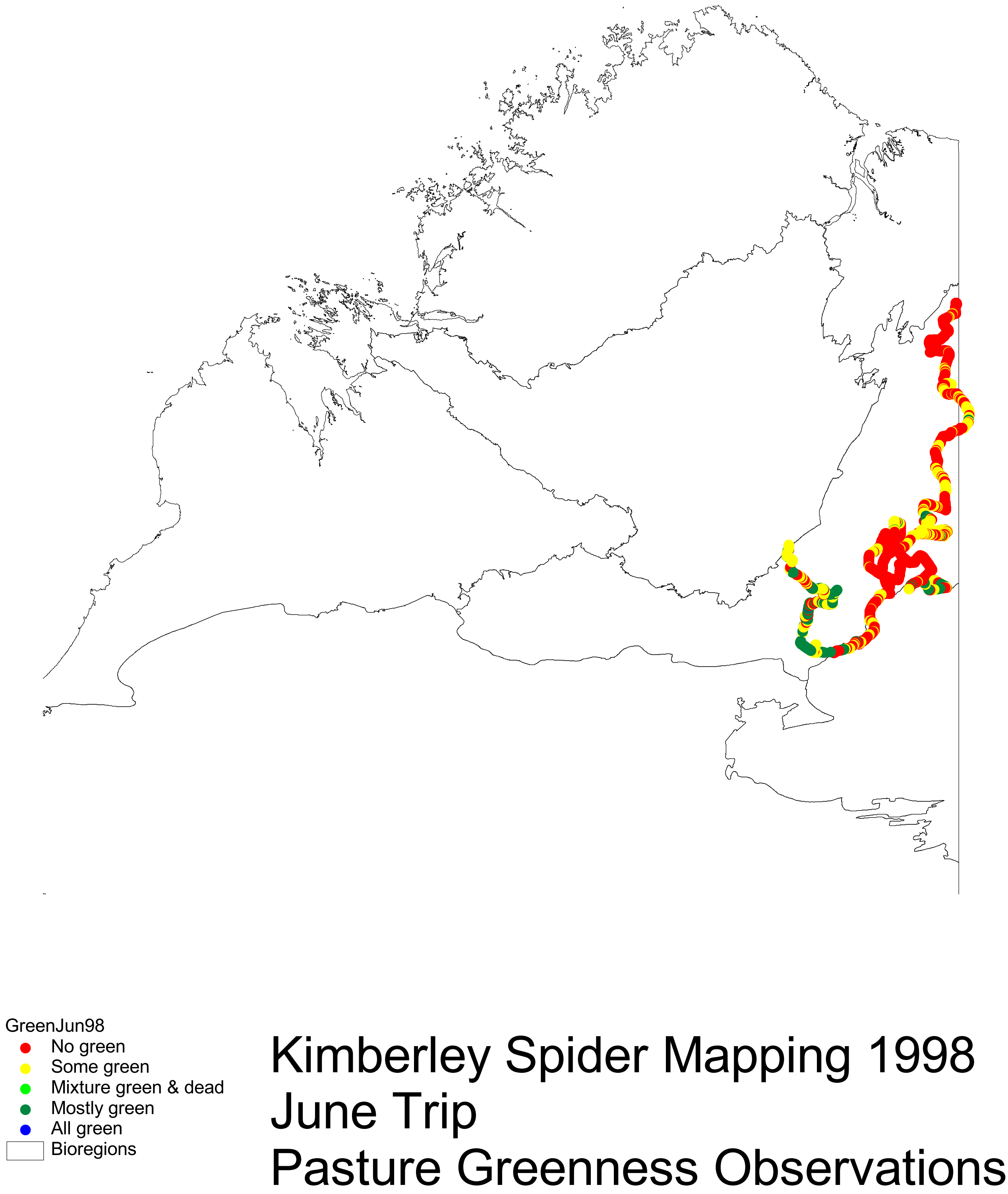


Figure 33. Kimberley spider mapping pasture greenness observations, June 1998.

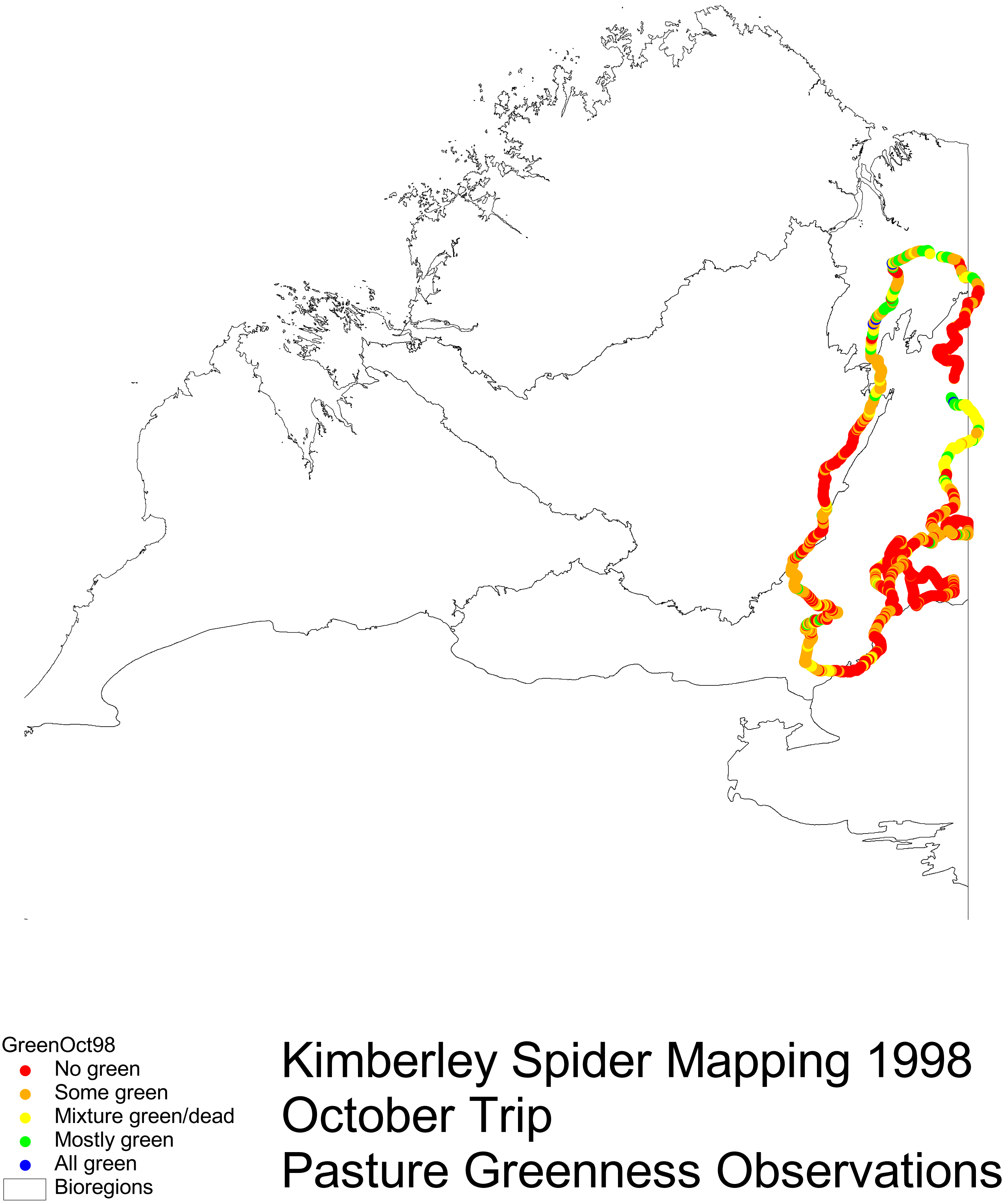


Figure 34. Kimberley spider mapping pasture greenness observations, October 1998.

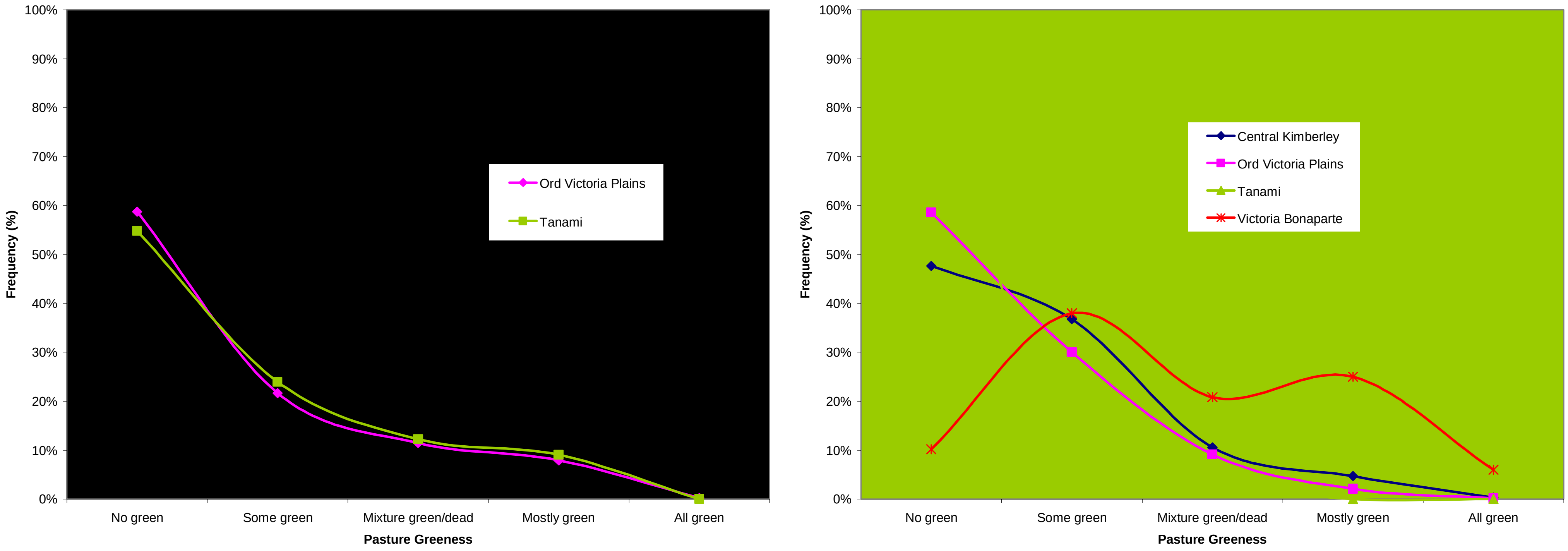


Figure 35. The distribution of pasture greenness classes in the early and late dry seasons for Kimberley bioregions in 1998.

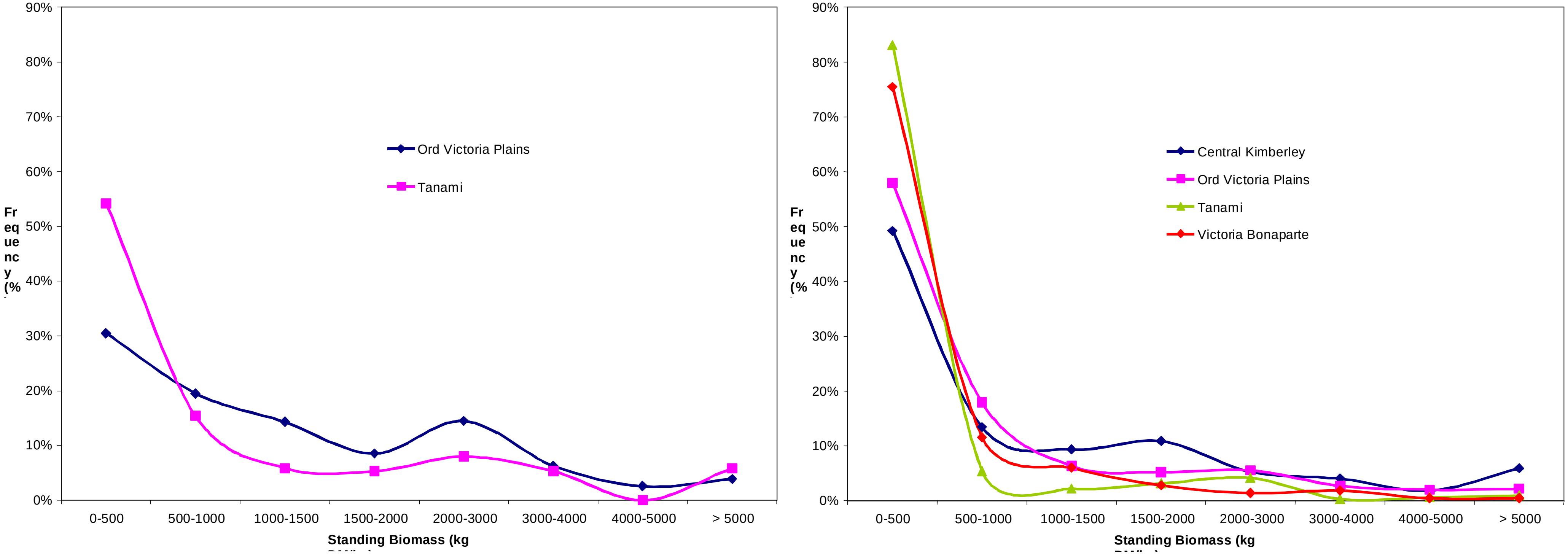


Figure 36. The distribution of standing biomass classes in the early and late dry seasons for Kimberley bioregions in 1998.

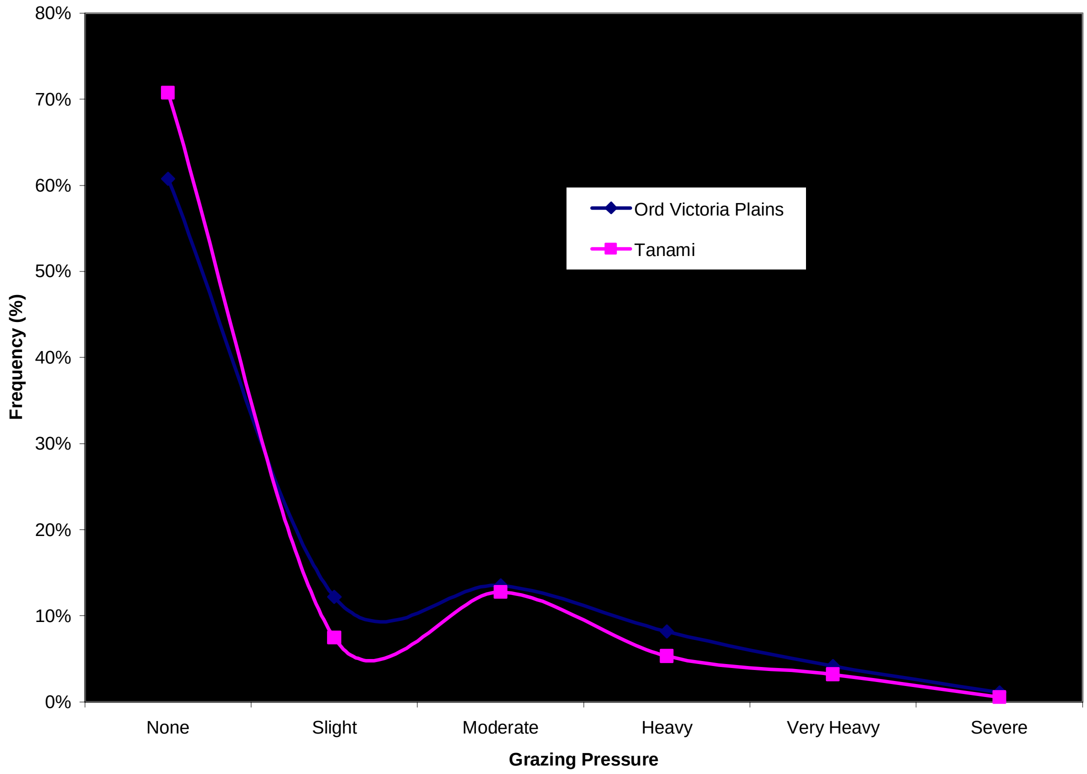


Figure 37. The distribution of grazing pressure classes in the early dry season for Kimberley bioregions in 1998.

Pasture biomass averages within vegetation 'super groups' derived from Beard's (1979) vegetation mapping, a finer scale classification of the Kimberley than bioregions, is presented in Table 9. As might be expected it shows much greater variation in yields than across the bioregions, with the highest level in *Triodia* hummock grassland (Code 46: 2735 kg DM/ha) and the lowest in short bunch grass/low savanna (Code 33: 171 kg DM/ha).

Greenness distributions in June were very similar for the sampled bioregions, the OVP and Tanami. At this time the 'no green' condition applied to more than 50% of observations, with only about 10% 'mostly green'. By October 1998, the two distributions showed marked differences. Change was subdued in the OVP, whereas the percentage of 'no green' increased to about 90% of observations in the more southerly Tanami. In 1998, the Central Kimberley and Victoria Bonaparte bioregions were sampled only in the late dry season. At that time, greenness distribution in the Central Kimberley was similar to that in the OVP. The Victoria Bonaparte, the most northerly bioregion sampled, was much greener than the others, probably reflecting a response to early storms.

Grazing pressure distributions in the OVP and Tanami were similar in the early dry season, with slight or nil grazing reported in over 70% of observations. Nevertheless, grazing in the OVP was classed as heavy or very heavy in more than 10% of observations.

Table 9. Average standing biomass (TSDM; kg DM/ha), observations (n) and mean standard error (SEM) measured for Kimberley vegetation communities (Supergroups; Beard 1979) in the early dry season (EDS) and late dry season (LDS), 1998.

Season	Code	Vegetation Description (Supergroup)	TSDM	n	SEM
EDS	29	**Grasslands, high grass savanna**; Mitchell grass, blue grass and sorghum *Astrebla* spp., *Dichanthium* spp., *Sorghum* spp.	1698	71	112
EDS	34	**Grasslands, short bunch grass savanna;** annual grasses *Enneapogon* spp., *Aristida* spp. etc. on dry plains and salt water grasses *Sporobolus virginicus* on the coast	828	894	33
EDS	35	**Grasslands, curly spinifex savanna woodland;** *Plectrachne pungens* with *E. phoenicea E. ferruginea* etc.	1157	24	262
EDS	36	**Grasslands, curly spinifex low-tree savanna with scattered trees**; *Plectrachne pungens* with *E. brevifolia E. dichromophloia*	1614	118	75
EDS	40	**Tree steppe; desert oak with soft spinifex** *Allocasuarina decaisneana* over *Triodia pungens*	757	151	77
EDS	43	**Shrub steppe; hummock grassland with scattered shrubs** mainly *Triodia* spp., *Acacia* spp., *Grevillea* spp. etc.	2081	728	62
EDS	45	**Sparse shrub steppe; hummock grassland with sparce shrubs** *Triodia* spp., *Acaia* spp	2025	74	232
EDS	46	**Grass steppe; hummock grassland** *Triodia* spp	2062	58	151
EDS	49	**Saltbush &/or bluebush with woodland or scattered trees;** e.g. salmon gum & gimlet *Atriplex* spp., *Maireana* spp. with *E. salmonophloia, E. salubris*	546	87	61
LDS	29	**Grasslands, high grass savanna;** Mitchell grass, blue grass and sorghum *Astrebla* spp., *Dichanthium* spp., *Sorghum* spp.	706	140	113
LDS	30	**Grasslands, tall bunch grass savanna woodland;** e.g. Grey box over ribbon grass *E. tectifica* over *Chrysopogon* spp	475	65	53
LDS	31	**Grasslands, tall bunch grass low-tree savanna;** Mainly ribbon grass with low woodland or scattered trees e.g. *E. terminalis* over *Chrysopogon* spp. and *Dichanthium* spp	353	64	53
LDS	33	**Grasslands, short bunch grass low-tree savanna;** short grasses with scattered trees e.g. Bauhinia and snappy gum *Enneapogon* spp. and *Aristida* spp. with *Lysiphyllum cunninghamii* and *E. brevifolia*	171	20	31
LDS	34	**Grasslands, short bunch grass savanna;** annual grasses *Enneapogon* spp., *Aristida* spp. etc. on dry plains and salt water grasses *Sporobolus virginicus* on the coast	402	1476	14
LDS	35	**Grasslands, curly spinifex savanna woodland;** *Plectrachne pungens* with *E. phoenicea, E. ferruginea* etc.	887	125	123
LDS	36	**Grasslands, curly spinifex low-tree savanna with scattered trees** *Plectrachne pungens* with *E. brevifolia, E. dichromophloia*	877	107	75
LDS	38	**Riverine sedgeland/grassland with trees**; Rivergum, coolabah over mixed sedges or tall bunch grass *E. camaldulensis, E. microtheca*	962	166	105
LDS	40	**Tree steppe; desert oak with soft spinifex;** *Allocasuarina decaisneana* over *Triodia pungens*	402	348	36
LDS	43	**Shrub steppe; hummock grassland with scattered shrubs** mainly *Triodia* spp., *Acacia* spp., *Grevillea* spp. etc.	1507	828	54
LDS	45	**Sparse shrub steppe; hummock grassland with sparce shrubs** *Triodia* spp., *Acaia* spp	954	49	133
LDS	46	**Grass steppe;** hummock grassland *Triodia* spp	2735	90	181
LDS	49	**Saltbush and/or bluebush with woodland or scattered trees;** e.g. salmon gum & gimlet *Atriplex* spp., *Maireana* spp. with *E. salmonophloia, E. salubris*	439	137	71

5.3.2.2 Kimberley 1999

The sampling route, and the classification of biomass and pasture greenness are shown in Figures 38 - 41. Average standing biomass and number of observations made throughout the bioregions in the Kimberley in 1999 are shown in Table 10. It should be noted that the extent of coverage varied greatly between 1998 and 1999 (Tables 8 and 10), and that sampling times were up to a month apart.

Table 10. Average standing biomass (TSDM; kg DM/ha), observations (n) and mean standard error (SEM) measured for Kimberley bioregions in 1999.

Bioregion	TSDM	n	SEM
Central Kimberley	2301	812	59
Dampierland	2022	5330	20
Ord Victoria Plains	2201	3536	30
Tanami	915	170	46
Victoria Bonaparte	1603	787	31

Estimated pasture biomass ranged from about 2300 kg DM/ha in the Central Kimberley, down to 900 kg DM/ha in the Tanami. Although bioregion averages varied between years, as would be expected, it was of interest that rankings among bioregions sampled in both years remained the same.

Pasture biomass distributions (Figure 41) were broad and quite complex reflecting the influence of climate, soils, fire and grazing. For all bioregions except the Tanami, observations fell into the 2,000-3,000 kg DM/ha class. In the Tanami the peak occurred at 500-1,000 kg DM/ha.

Pasture biomass averages within vegetation ‘super groups’ derived from Beard’s (1979) vegetation mapping of the Kimberley are presented in Table 11.

In 1999, as in 1998, the greenness distributions in central Kimberley and OVP were similar, with about 55% of observations classified ‘no green’ (Figure 40). Much drier conditions were apparent in the Tanami, with about 90% of observations classified ‘no green’.

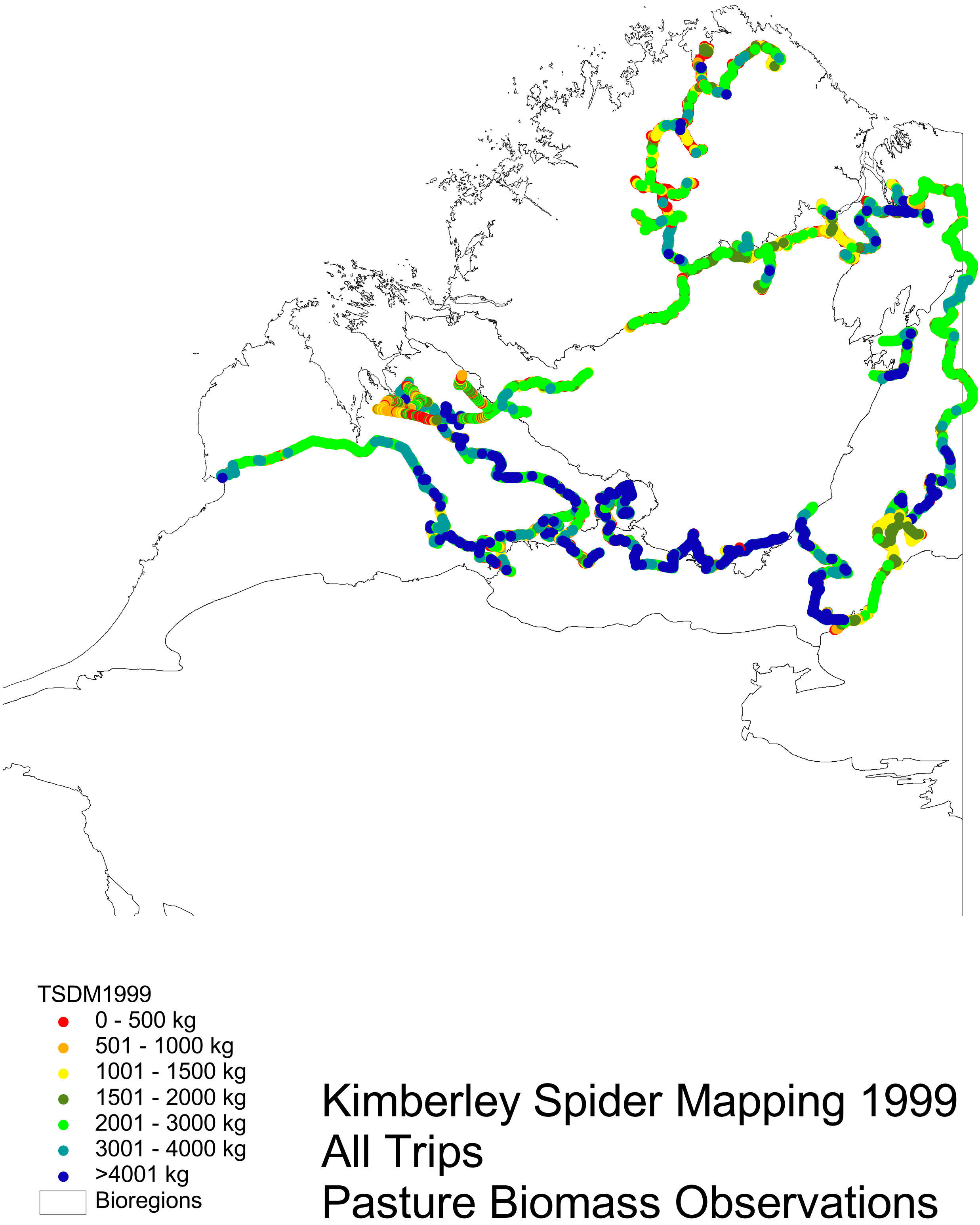


Figure 38. Kimberley spider mapping biomass observations, 1999.

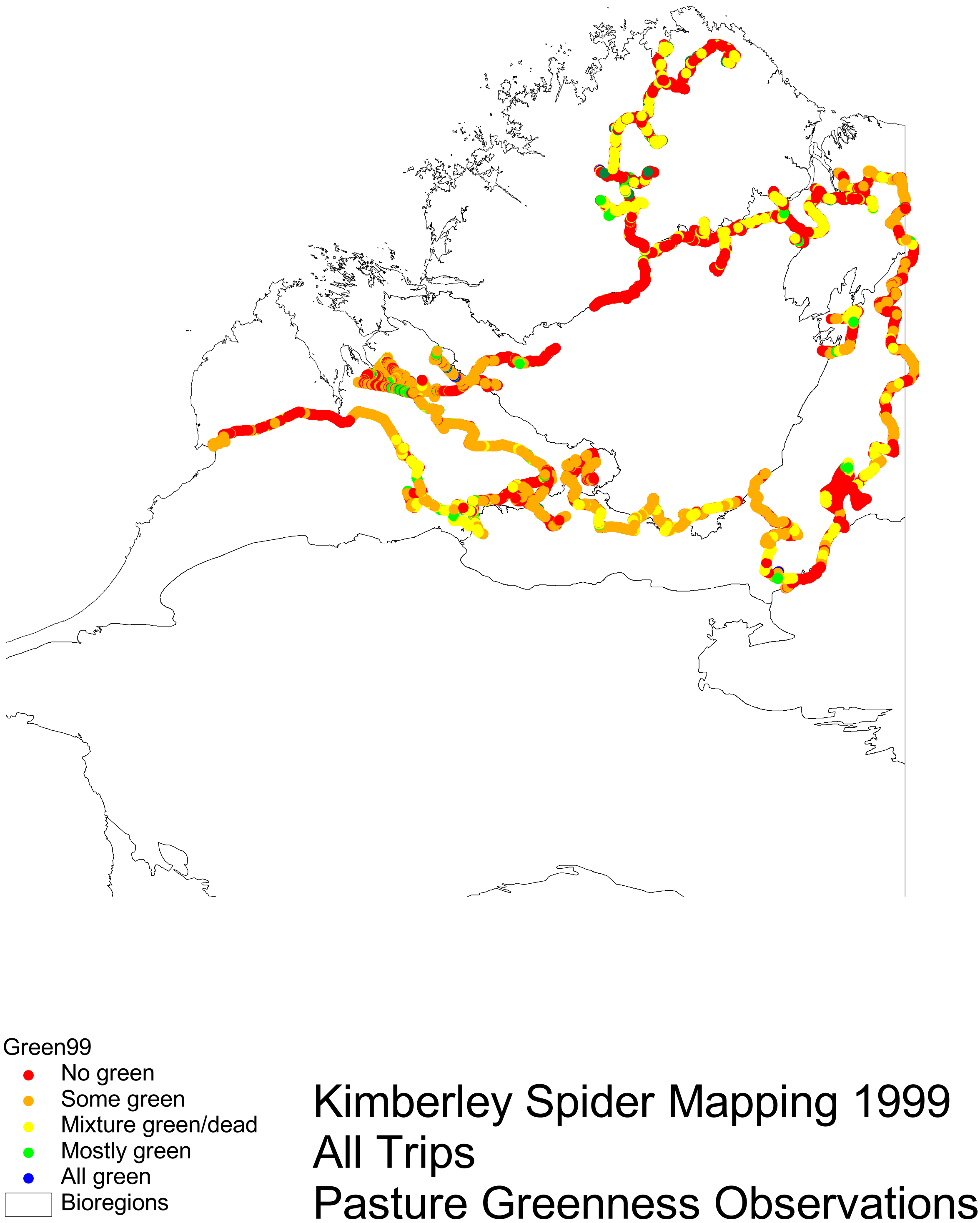


Figure 39. Kimberley spider mapping pasture greenness observations, 1999.

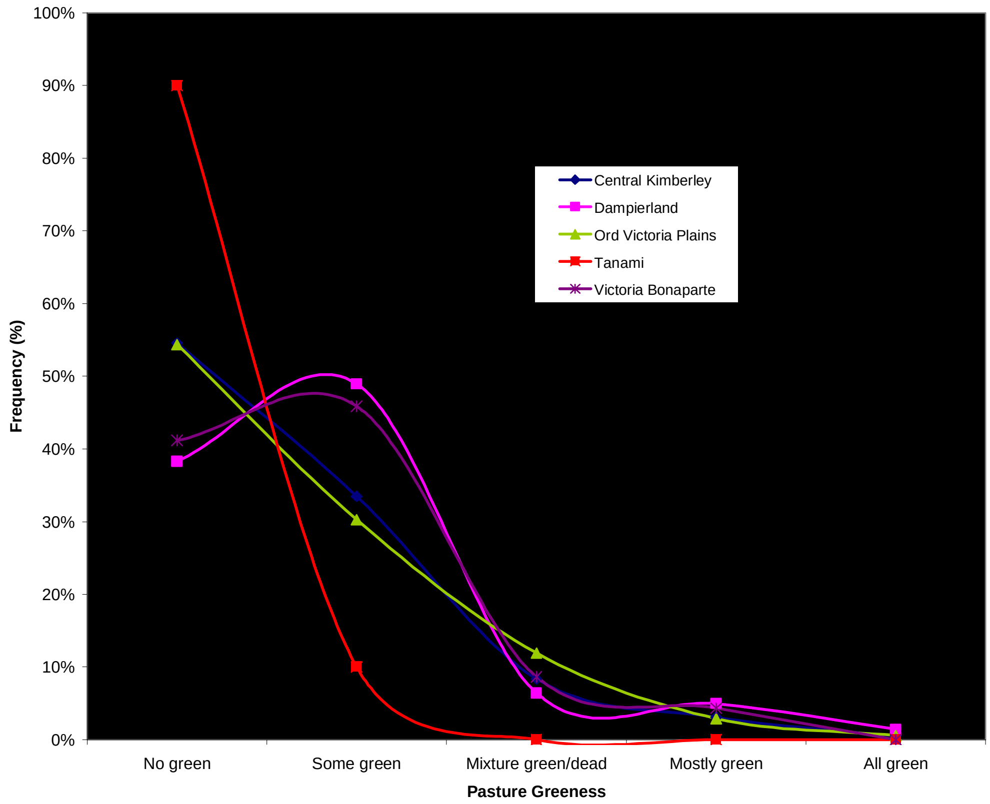


Figure 40. The distribution of pasture greenness classes for bioregions in the Kimberley region in 1999.

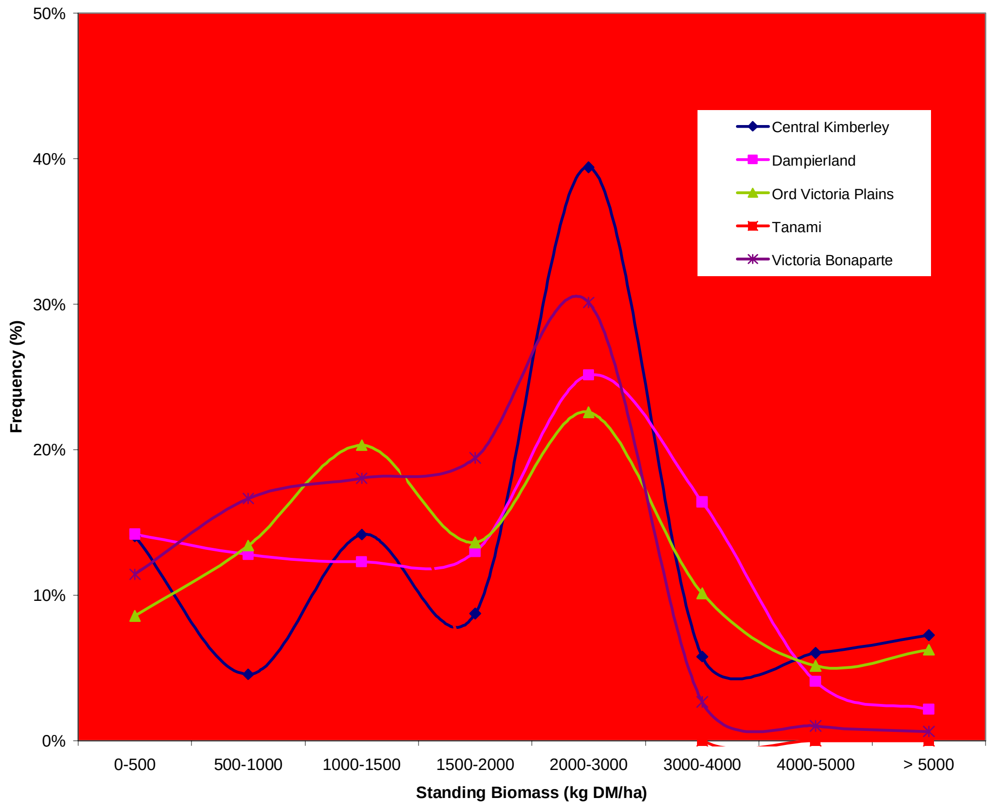


Figure 41. The distribution of standing biomass classes for bioregions in the Kimberley region, 1999.

Table 11. Average standing biomass (TSDM; kg DM/ha), observations (n) and mean standard error (SEM) measured for Kimberley vegetation communities (Supergroups; Beard 1979) in 1999.

Code	Vegetation Description (Supergroup)	TSDM	n	SEM
5	**Open woodland;** marri, wandoo and rivergum *E. calophylla, E. wandoo, E. camaldulensis*	1651	46	163
27	**Grasslands, high grass savanna woodland on basalt;** Grey box, cabbage gum over white grass and ribbon grass *E. tectifica, E. grandifolia* over *Sehima nervosum, Chrysopogon* spp.	1965	138	81
28	**Grasslands, high grass savanna woodland on sandstone;** Bloodwood, Stringybark over curley spinifex and sorghum *E. dichromophloia, E. tetrodonta* over *Plectrachne pungens, Sorghum* spp.	1800	1427	40
29	**Grasslands, high grass savanna;** Mitchell grass, blue grass and sorghum *Astrebla* spp., *Dichanthium* spp., and *Sorghum* spp	1921	240	51
30	**Grasslands, tall bunch grass savanna woodland;** e.g. Grey box over ribbon grass *E. tectifica* over *Chrysopogon* spp.	1556	395	33
31	**Grasslands, tall bunch grass low-tree savanna;** Mainly ribbon grass with low woodland or scattered trees e.g. *E. terminalis* over *Chrysopogon* spp. *Dichanthium* spp.	1824	271	71
32	**Grasslands, tall bunch grass savanna;** mainly Mitchell grass *Astrebla* spp.	2214	7	239
33	**Grasslands, short bunch grass low-tree savanna;** short grasses with scattered trees e.g. Bauhinia and snappy gum *Enneapogon* spp., *Aristida* spp. with *Lysiphyllum cunninghamii* and *E. brevifolia*	2396	615	65
34	**Grasslands, short bunch grass savanna;** annual grasses *Enneapogon* spp. *Aristida* spp. etc. on dry plains and salt water grasses *Sporobolus virginicus* on the coast	1830	4328	20
35	**Grasslands, curly spinifex savanna woodland;** *Plectrachne pungens* with *E. phoenicea, E. ferruginea* etc.	2277	89	143
36	**Grasslands, curly spinifex low-tree savanna with scattered trees;** *Plectrachne pungens* with *E. brevifolia, E. dichromophloia*	1883	192	89
38	**Riverine sedgeland/grassland with trees;** Rivergum, coolabah over mixed sedges or tall bunch grass with *E. camaldulensis, E. microtheca*	2530	299	122
39	**Sedgeland;** (mainly in the south-west) Cyperaceae, Restionaceae, Juncaceae	2286	490	59
40	**Tree steppe;** desert oak with soft spinifex *Allocasuarina decaisneana* over *Triodia pungens*	1093	300	41
43	**Shrub steppe;** hummock grassland with scattered shrubs mainly *Triodia* spp. *Acacia* spp., *Grevillea* spp. etc.	3167	929	86
44	**Sparce low tree steppe;** hummock grassland with sparse eucalypts, e.g. bloodwood & snappy gum *Triodia* spp. with *E. dichromophloia, E. brevifolia*	1764	116	171
45	**Sparse shrub steppe;** hummock grassland with sparse shrubs, e.g. *Triodia* spp., Acacia spp.	2989	278	131
46	**Grass steppe;** hummock grassland *Triodia* spp.	3125	176	169
48	**Samphire with thicket & scattered trees;** e.g. tea tree withYork gum, *Casuarina halosarcia* with *Melaleuca* spp. and *E. loxophleba, Allocasuarina obesa*	2637	87	133
49	**Saltbush and/or bluebush with woodland or scattered trees;** e.g. salmon gum and gimlet *Atriplex maireana* with *E. salmonophloia, E. salubris*	965	19	86

6 Calibration and validation of the spatial model

The Aussie GRASS model is a largely empirical model, representing the processes of soil water change, pasture growth, death, detachment and consumption by animals. These processes are modified by parameters, some of which remain essentially fixed for all pasture communities, and some of which vary.

The current operational model is parameterised using: 1) data on pasture yield collected by field observation; and 2) greenness data (Normalised Difference Vegetation Index - NDVI) from the NOAA satellite. Field observations include detailed soil and pasture data collected using the SWIFTSYND technique, and coarser data collected using the spider mapping technique. Within this sub-project, SWIFTSYND sites were used to develop parameter sets for several important land systems found within the NT and Kimberley. These parameter sets were then used as a guide and to estimate bounds for parameters as part of the calibration process. Over 110,000 observation points collected under Objective 2 were then used to calibrate and validate these and other land systems covered within the spider mapping exercise.

Calibration is an ongoing activity of constant model improvement which is necessary whenever additional observations become available, when model functionality changes (e.g. fires added to the model), and if input layers are changed (e.g. tree basal area or rainfall). During the calibration process, parameters were constrained to the extent that the model:

1. reproduced mean yield and greenness data (usually to within 5% of the measured values);
2. produced a reasonable replication of the time series of greenness from the NOAA satellites;
3. parameters, where applicable, did not vary greatly from those obtained from SWIFTSYND data;
4. parameters were consistent for similar vegetation types;
5. produced plausible maps of pasture biomass and growth;
6. generally did not produce artificial boundaries in output maps; and
7. produced mean drainage division runoff to within 30% (measurement error), or better, of reported values.

The spider mapping field data set was split into two groups for calibration (66.6%) and validation (33.3%). The calibration data were used to adjust parameters while the remaining data were withheld from this process and used as a check on model performance. Observations falling within a given pixel (25 km^2) on a given day were averaged to give a single pixel value. This process was done separately for ‘calibration’ and ‘validation’ observations. These pixel values then were used as the basis for the calibration and validation process.

Following evaluation of the performance statistics and acceptance of this report, it is intended to recombine the two data sets to maximise model calibration. Hence it is expected that the final calibration results will be an improvement on the calibration and validation results presented in this report.

It should be noted that, as a general rule-of-thumb, the resolution of the model and associated inputs means that the Aussie GRASS model can only be expected to approach the true mean for clusters of 30 for more pixels, or in other words, approximately ¼ of a Statistical Local Area as mapped by the Australian Bureau of Statistics.

6.1 Results

The calibration and validation results for the NT and Kimberley using the spider mapping data are presented in Figures 42 and 43. Each of the data points in these graphs represents the mean of all calibration or validation observations, on a pixel basis, made within a specific Aussie GRASS vegetation community during the spider mapping program. Whilst these results give an indication of the ability of the model to simulate mean biomass levels for different vegetation communities, they do not provide any information on the ability of the model to account for within season and seasonal variation within a given community. To overcome this problem it is necessary to do repeated sampling for each of the communities across a number of seasons. An alternative, cheaper approach is to plot the time series of model greenness against NOAA satellite NDVI values for each the communities. The results of this form of calibration are shown in Figure 44 for all communities within the NT and Kimberley in terms of mean NDVI values, and in Figures 45-49 as a time series for selected communities.

6.2 Calibration issues

Despite the use of the constraints described above during the calibration process, it is still possible to obtain non-unique solutions in parameter space. Major issues identified as a result of this and earlier calibration exercises were:

- Calibration without direct measurements of growth, water use by plant communities, and nitrogen uptake limits the ability to constrain parameters in parameter space. Hence the availability of the SWIFTSYND data for communities in the VRD proved very useful, both there and in related areas.
- Errors in the tree density map where basal area was over- or underestimated by one or two units (m^2/ha). These errors are most noticeable in coastal and sub-coastal areas where tree density was underestimated.
- Noise in the NDVI signal related to sun angle and bi-directional reflectance (largely associated with tree canopy illumination and shadow), cloud contamination etc.
- Fire scars maps were not available pre-1999 to reset biomass and NDVI.

Future near-term developments are planned to include the following:

- Automatic calibration - it should be possible to use advanced mathematical tools to automatically calibrate model parameters. These techniques have been used on older ‘test’ versions of a Queensland-only spatial model, and on point models. However the complexity of running these tools effectively in a supercomputing environment has slowed development of this capability.
- Improved correction of noise in the NDVI calibration data.
- Incorporation of better tree mapping data from Landsat TM analyses.

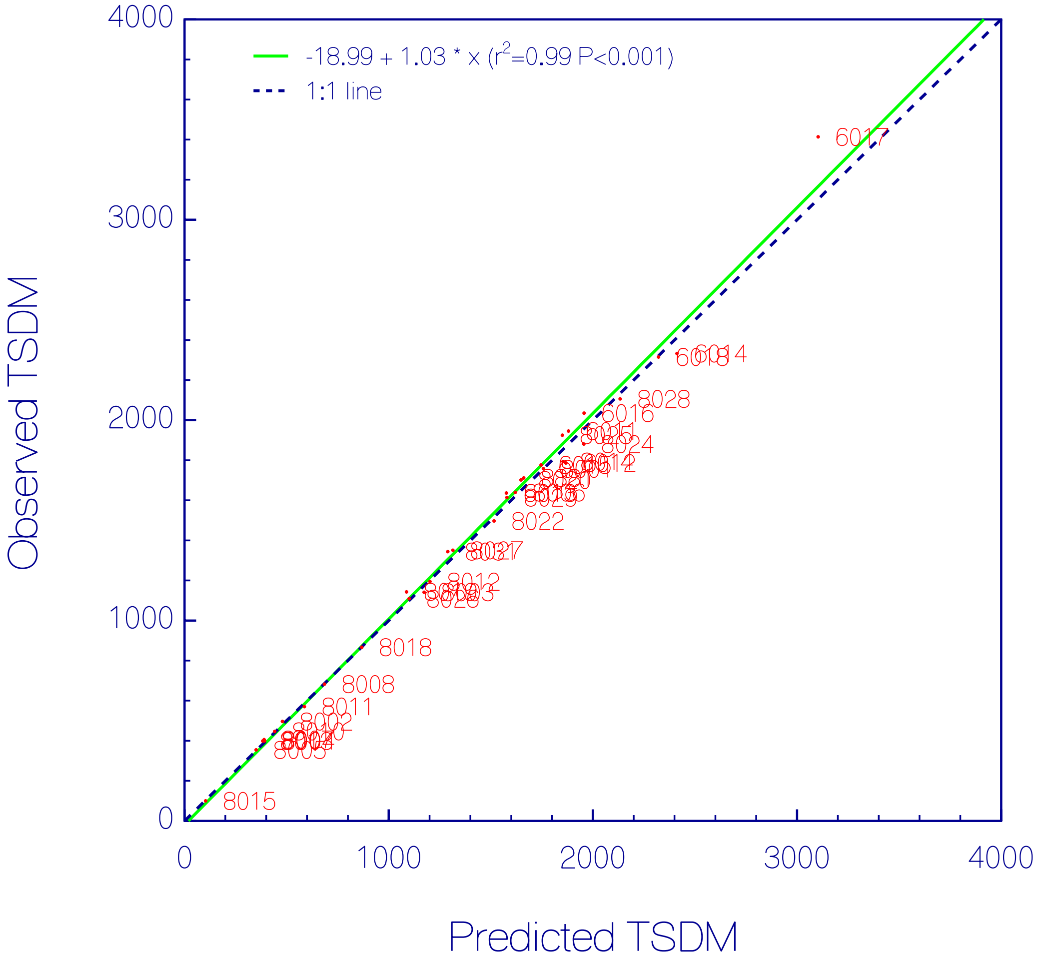


Figure 42. Observed and predicted TSDM values for NT and Kimberley vegetation communities following calibration. The observed values for each community represent the mean of all calibration observations, on a pixel basis, for that community collected as part of the spider mapping program. The predicted value for each vegetation community is the mean of all values for the same pixels and on the same dates as the observations were made. The labels for each of the data points are the vegetation codes for each of the communities as used within the Aussie GRASS model.

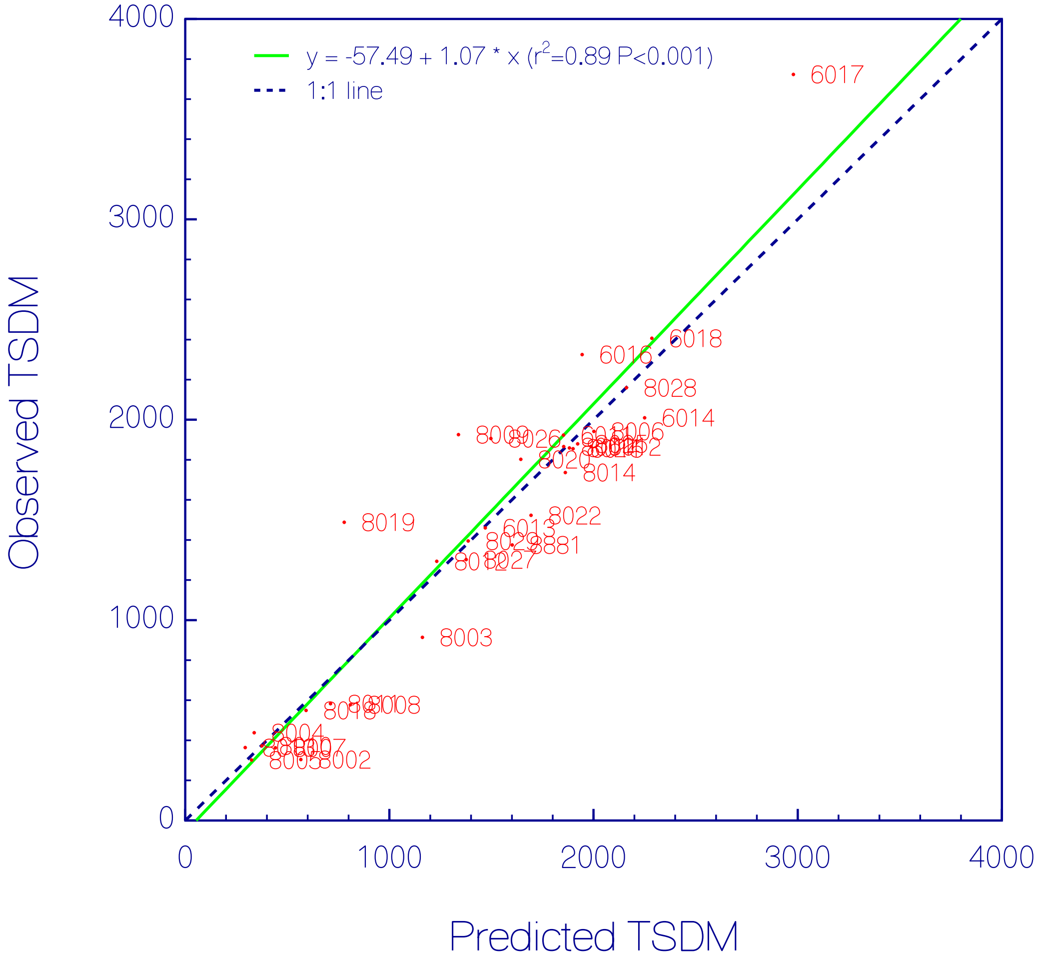


Figure 43. Observed and predicted TSDM values for NT and Kimberley vegetation communities following validation. The observed values for each community represent the mean of all validation observations, on a pixel basis, for that community collected as part of the spider mapping program. The predicted value for each vegetation community is the mean of all values for the same pixels and on the same dates as the observations were made. The labels for each of the data points are the vegetation codes for each of the communities as used within the Aussie GRASS model.

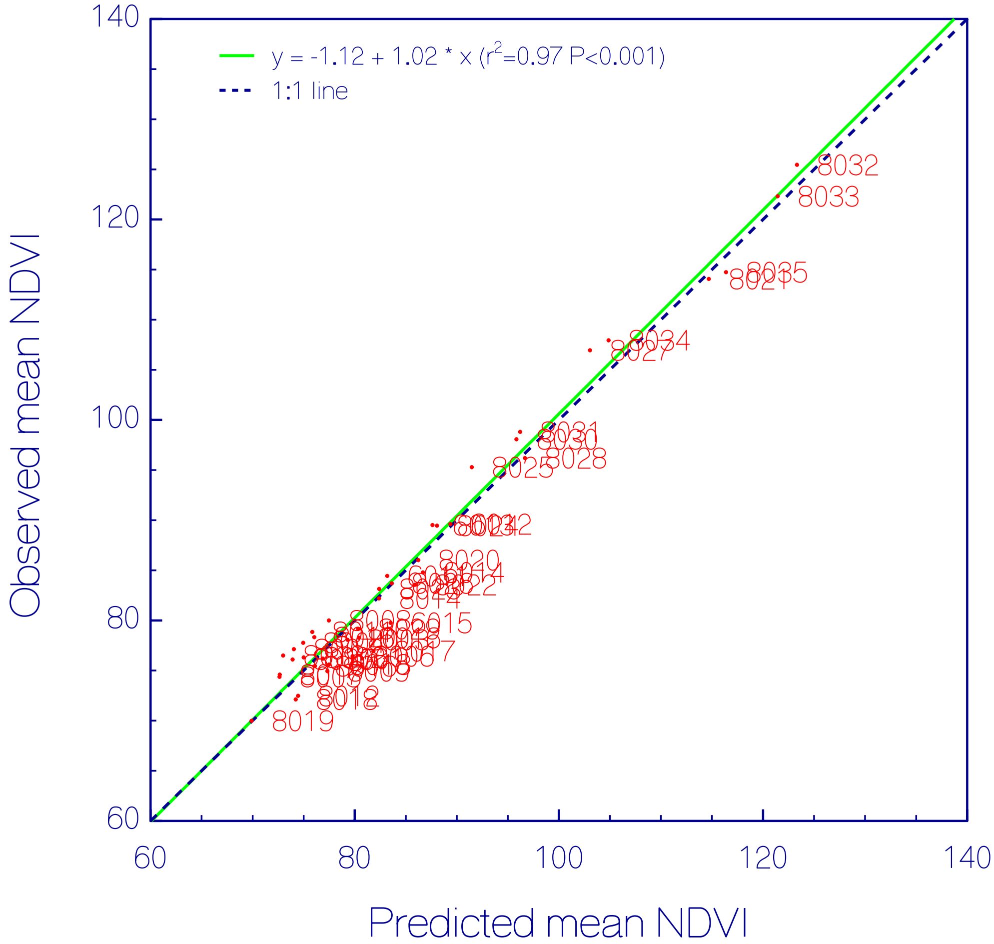


Figure 44. Observed and predicted mean NDVI values for NT and Kimberley vegetation communities for the period 1982-1992 following calibration.

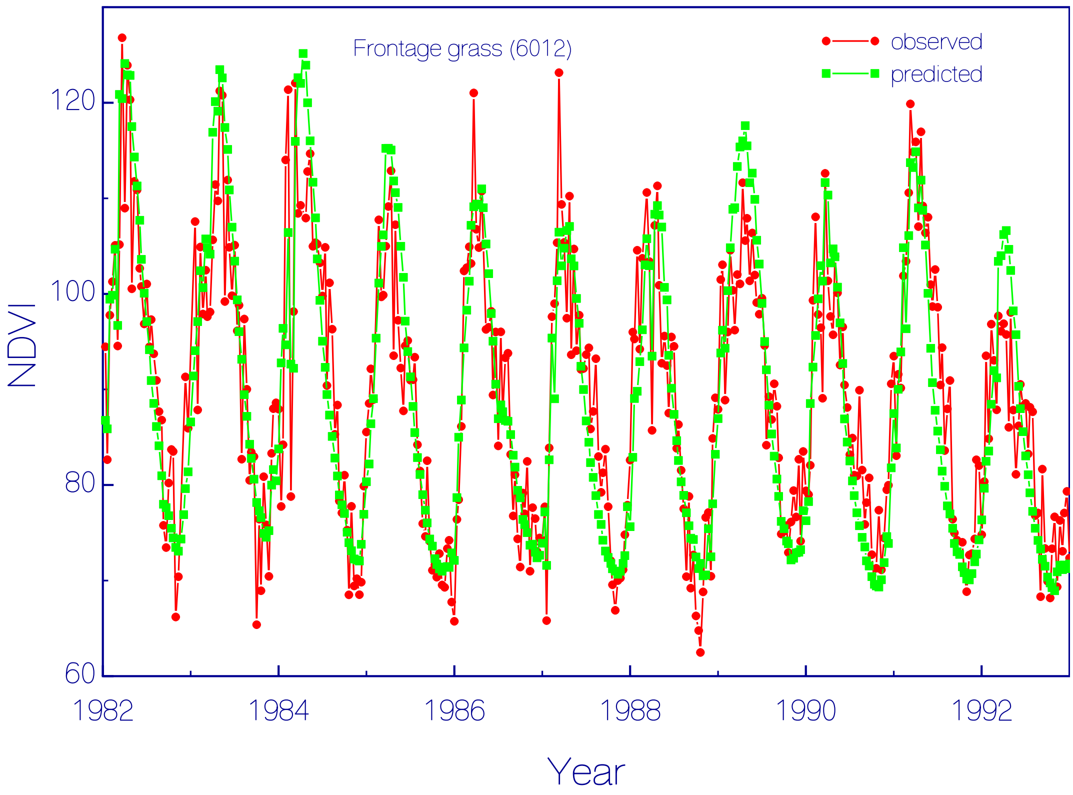


Figure 45. Time series of observed and predicted NDVI values for the frontage grass community (6012) of WA.

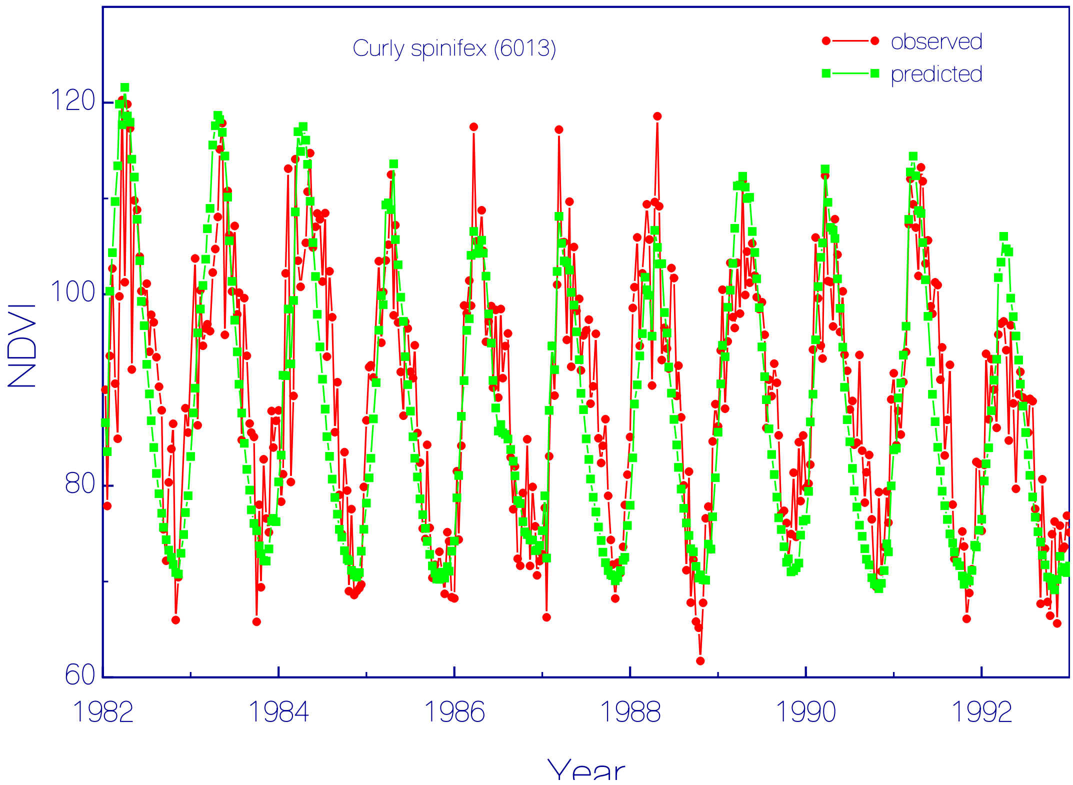


Figure 46. Time series of observed and predicted NDVI values for the curly spinifex community (6013) of WA.

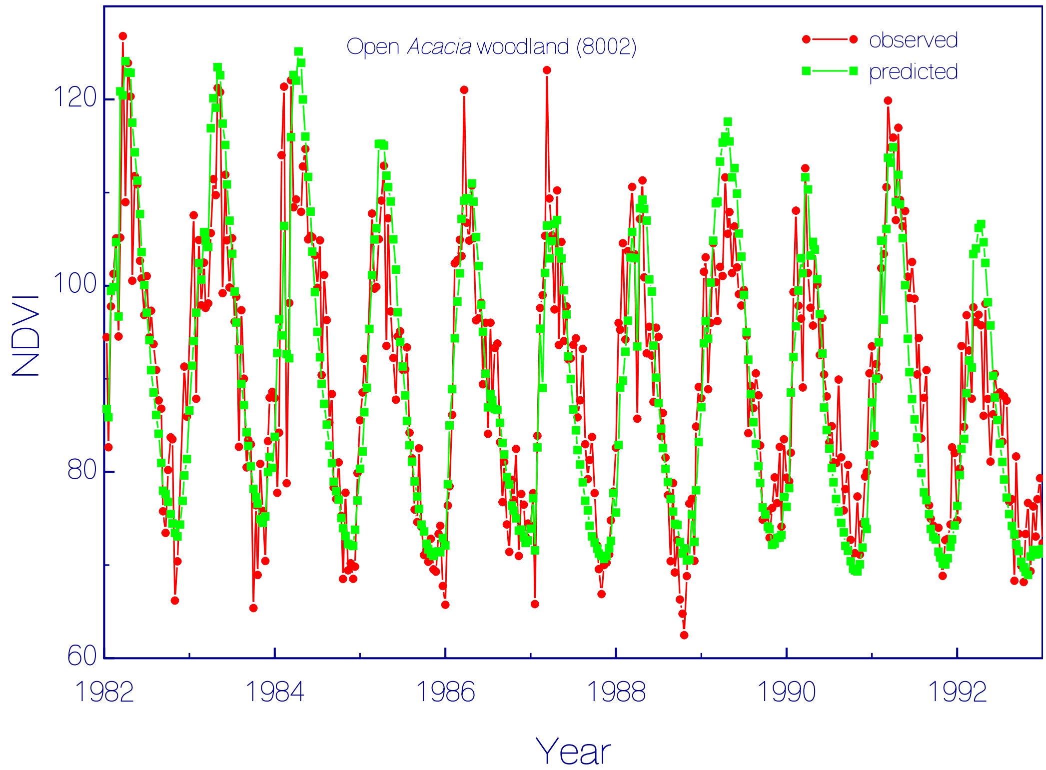


Figure 47. Time series of observed and predicted NDVI values for the open *Acacia* woodland (mainly *Acacia aneura*) over mixed grassland community (8002) of the NT.

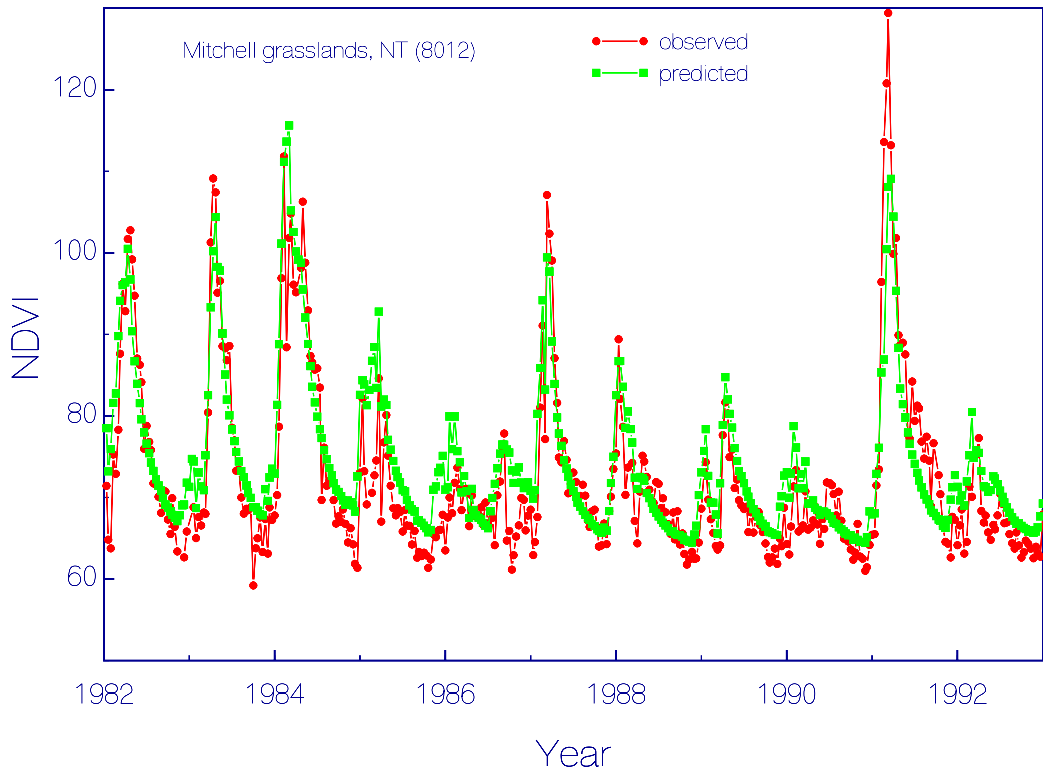


Figure 48. Time series of observed and predicted NDVI values for the Mitchell grassland (*Astrebla* spp.) community (8012) of the NT.

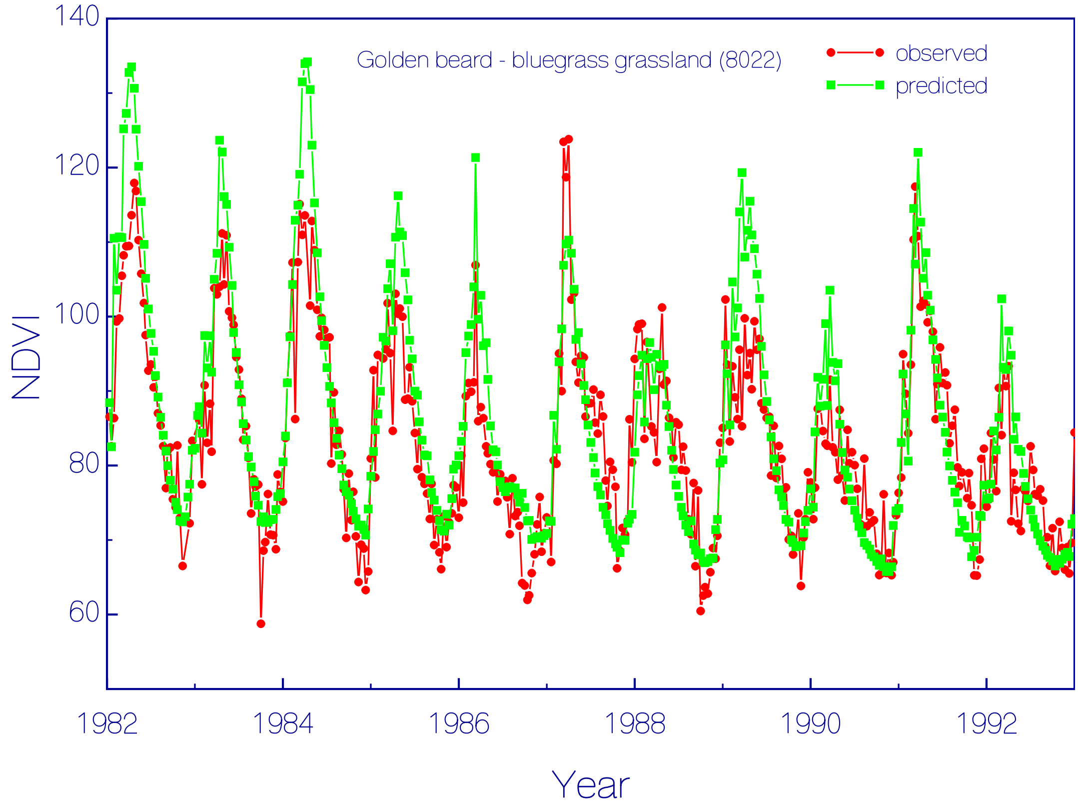


Figure 49. Time series of observed and predicted NDVI values for the golden beard (*Chrysopogon fallax*) - bluegrass (*Dicanthium fecundum*) grassland community (8022) of the NT.

7 Aussie GRASS products and seasonal conditions

Examples of Aussie GRASS products displaying relative rainfall, relative pasture growth, and standing biomass during 1997-98 and 1998-99 for the NT and WA are shown in Figures 50-61. These products describe modelled seasonal conditions experienced during the period of field data collection. Throughout the Katherine region the 1997-98 growing season rainfall was very patchy resulting in below average simulated pasture growth in many areas. In 1998-99, rainfall and simulated pasture growth in the Katherine region and the Top End generally were well above average. Areas of below average growth were simulated for the Barkly Tableland and central-eastern Australia. During this season model estimates of TSDM were very low (< 1,000 kg DM/ha) throughout much of central Australia.

In 1997-98 above average rainfall in the western Kimberley resulted in excellent simulated pasture growth. Simulated pasture growth in drier southern areas of the east Kimberley were below average. During 1998-99, rainfall and predicted pasture growth were well above average throughout the entire Kimberley region.

In both seasons the patterns of predicted pasture growth across the NT and Kimberley closely matched the general trends observed in actual pasture growth.

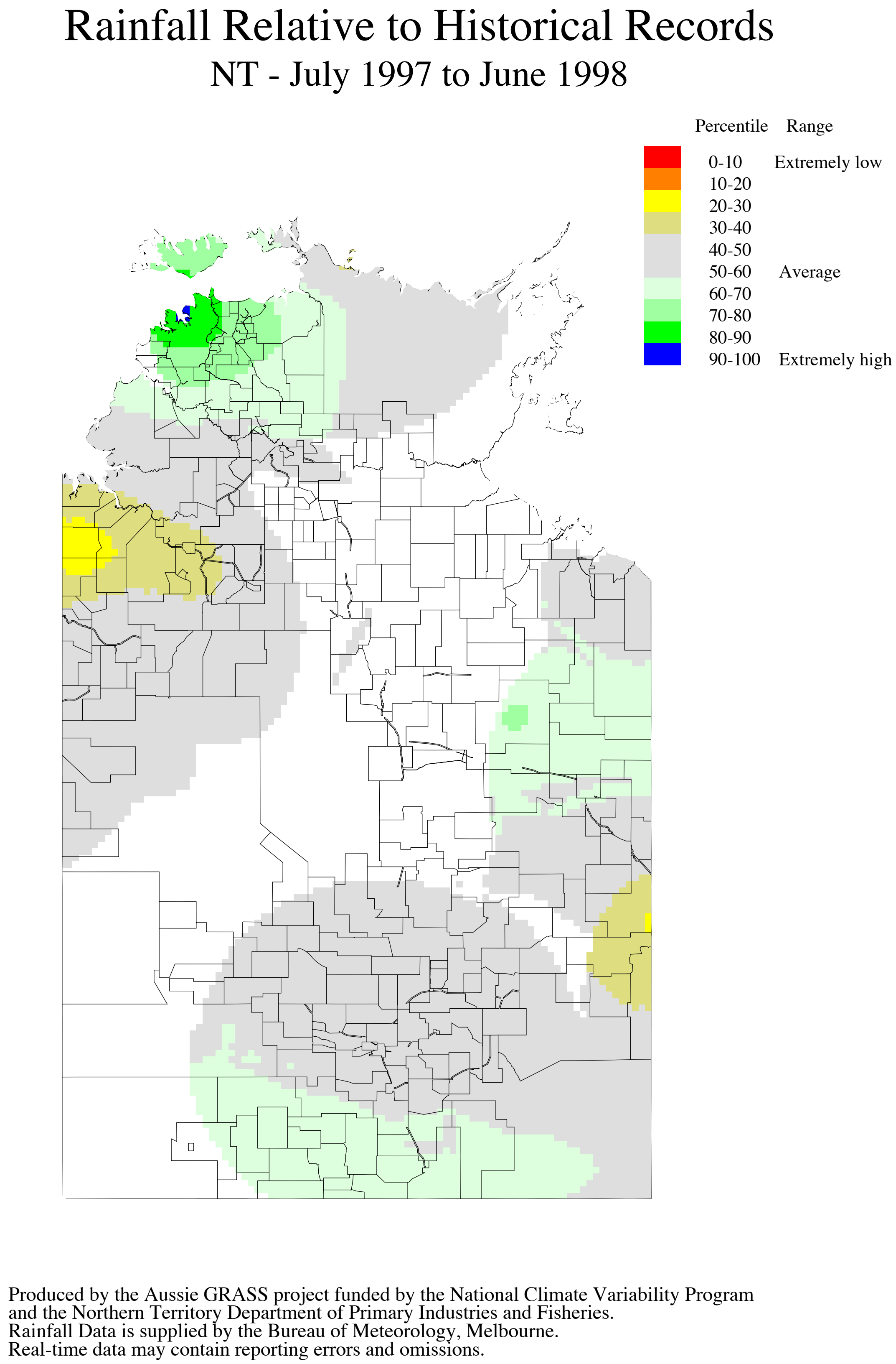


Figure 50. NT relative rainfall map for the 12-month period up to and including June 1998.

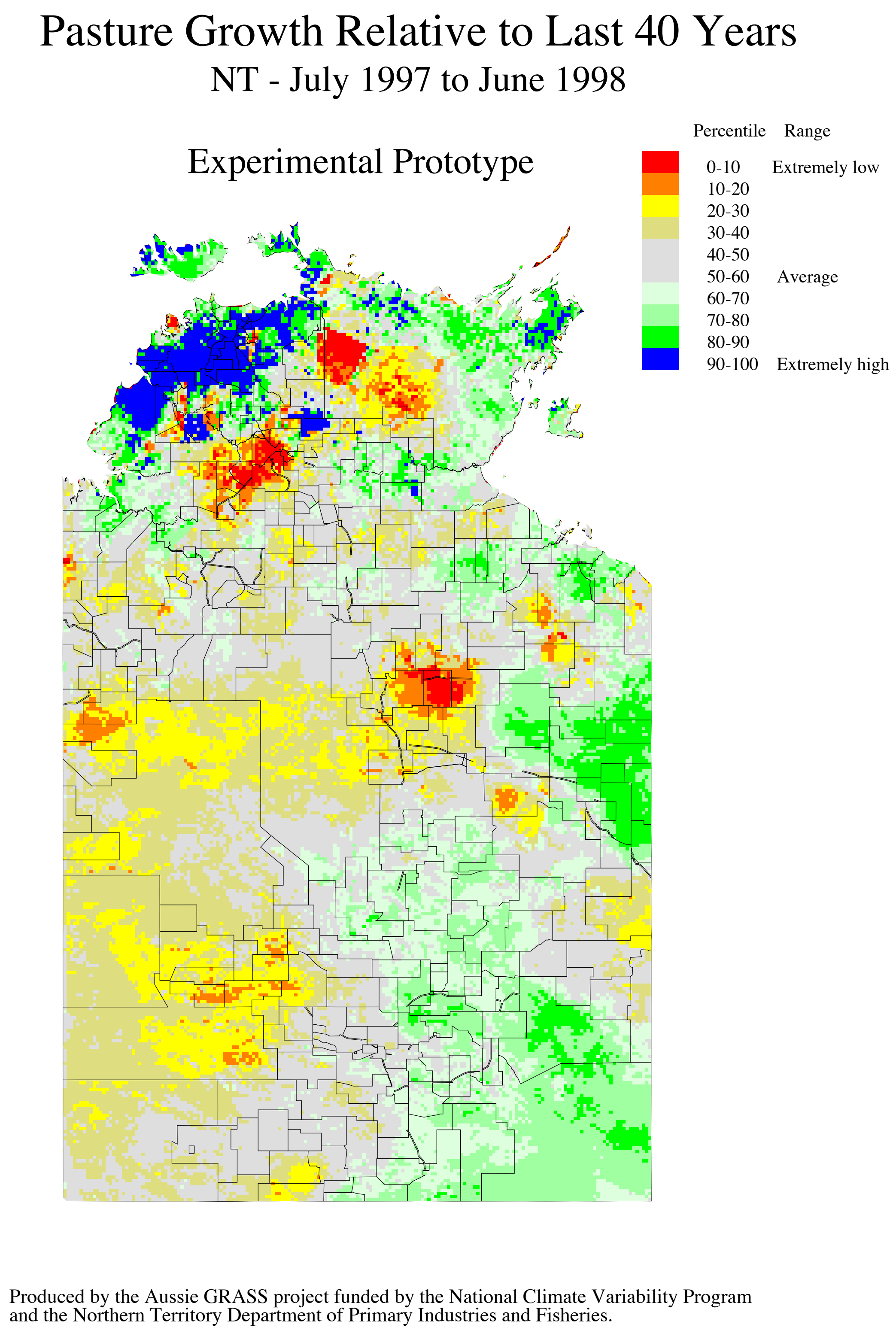


Figure 51. Simulated NT relative pasture growth map for the 12-month period up to and including June 1998.

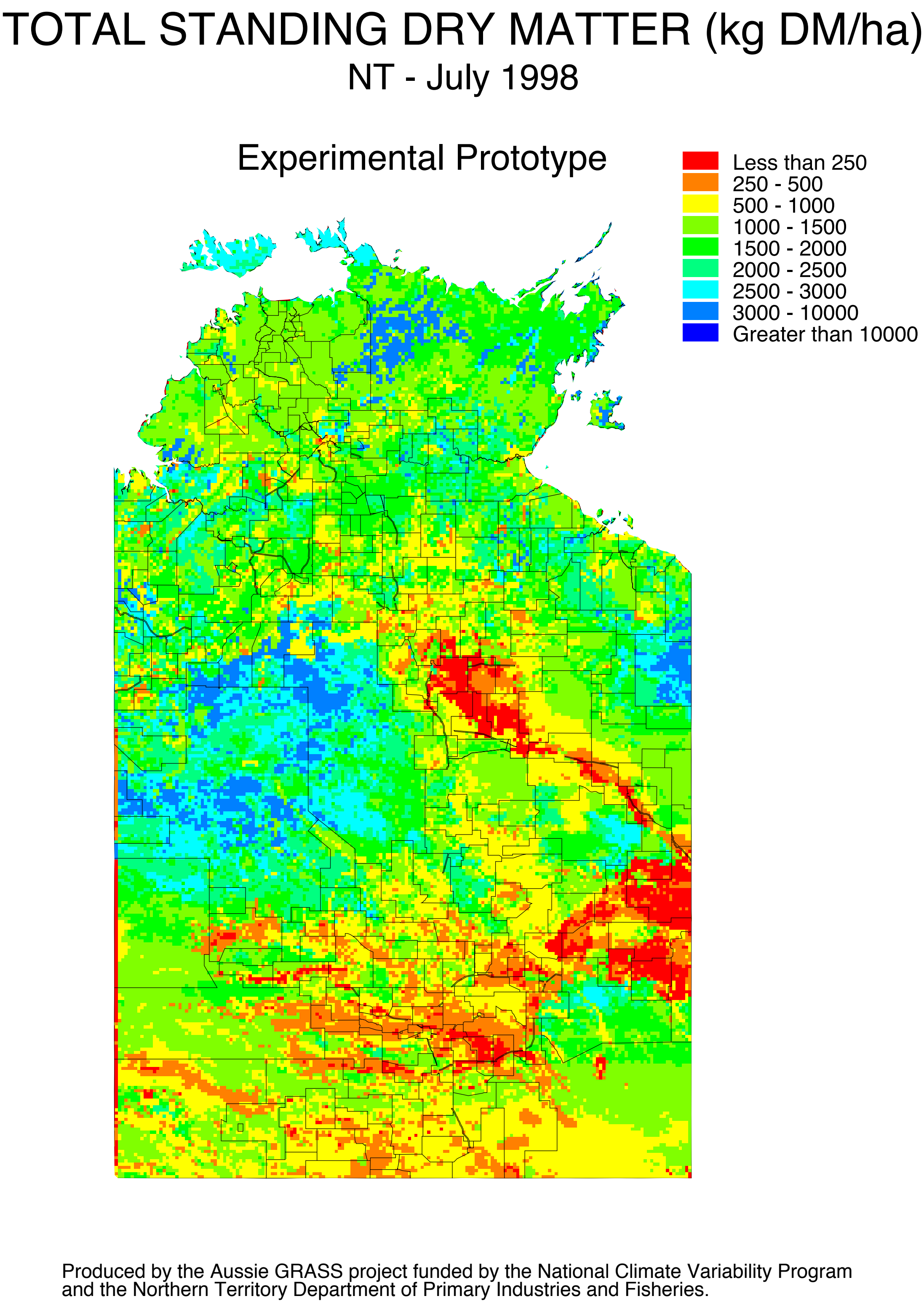
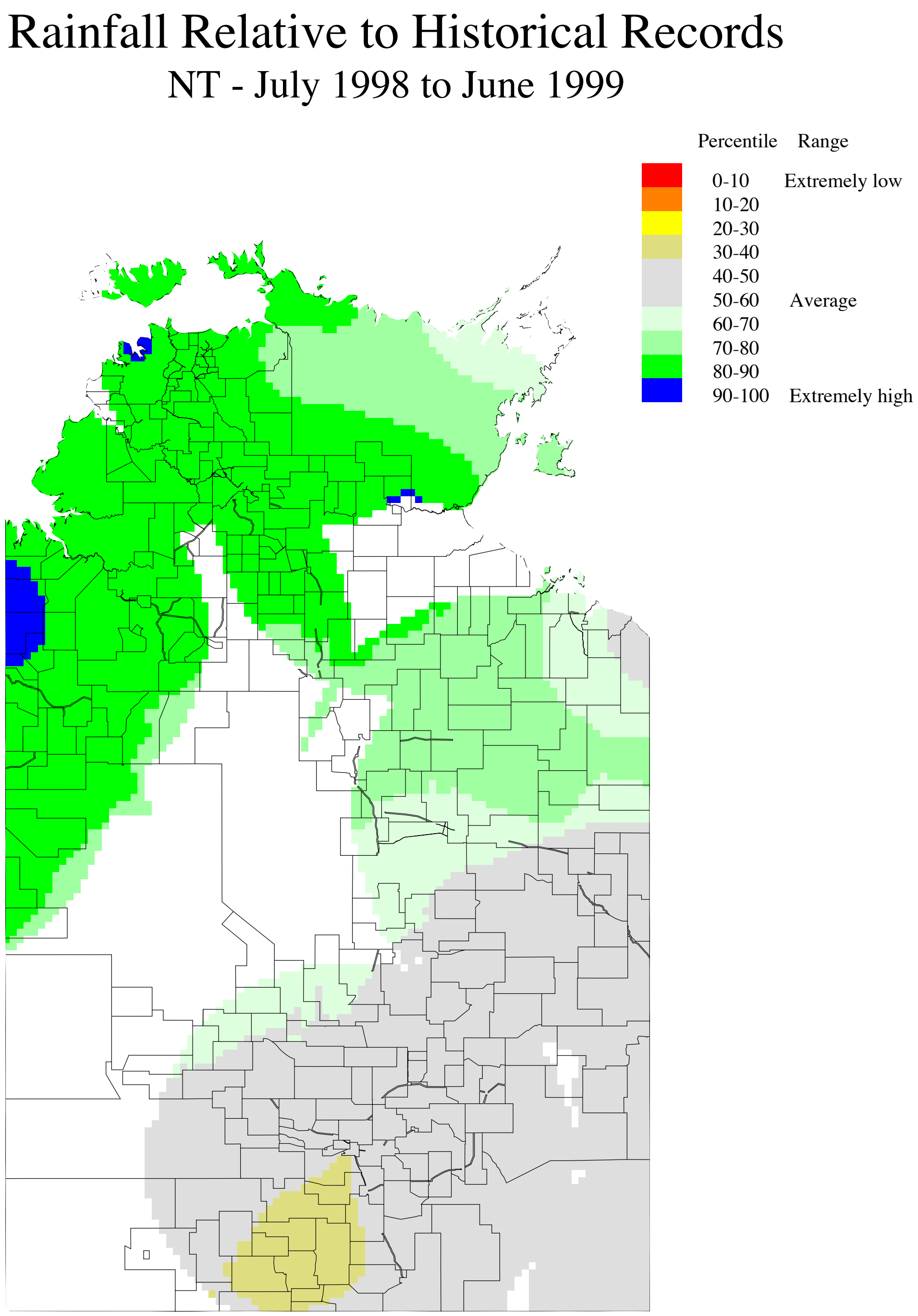


Figure 52. Simulated NT standing biomass map as at the end of July 1998.



Produced by the Aussie GRASS project funded by the National Climate Variability Program and the Northern Territory Department of Primary Industries and Fisheries.
Rainfall Data is supplied by the Bureau of Meteorology, Melbourne.
Real-time data may contain reporting errors and omissions.

Figure 53. NT relative rainfall map for the 12-month period up to and including June 1999.

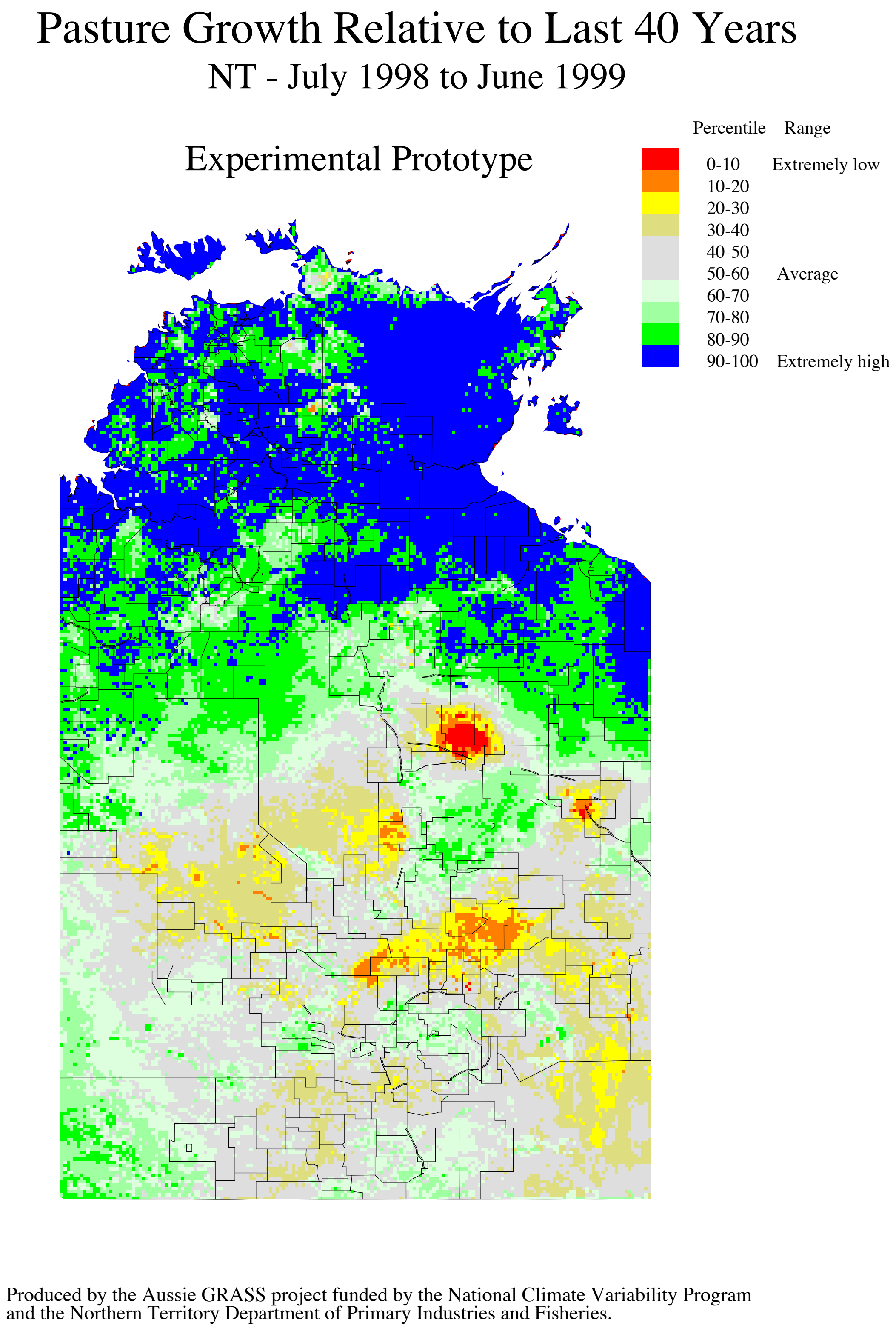


Figure 54. Simulated NT relative pasture growth map for the 12-month period up to and including June 1999.

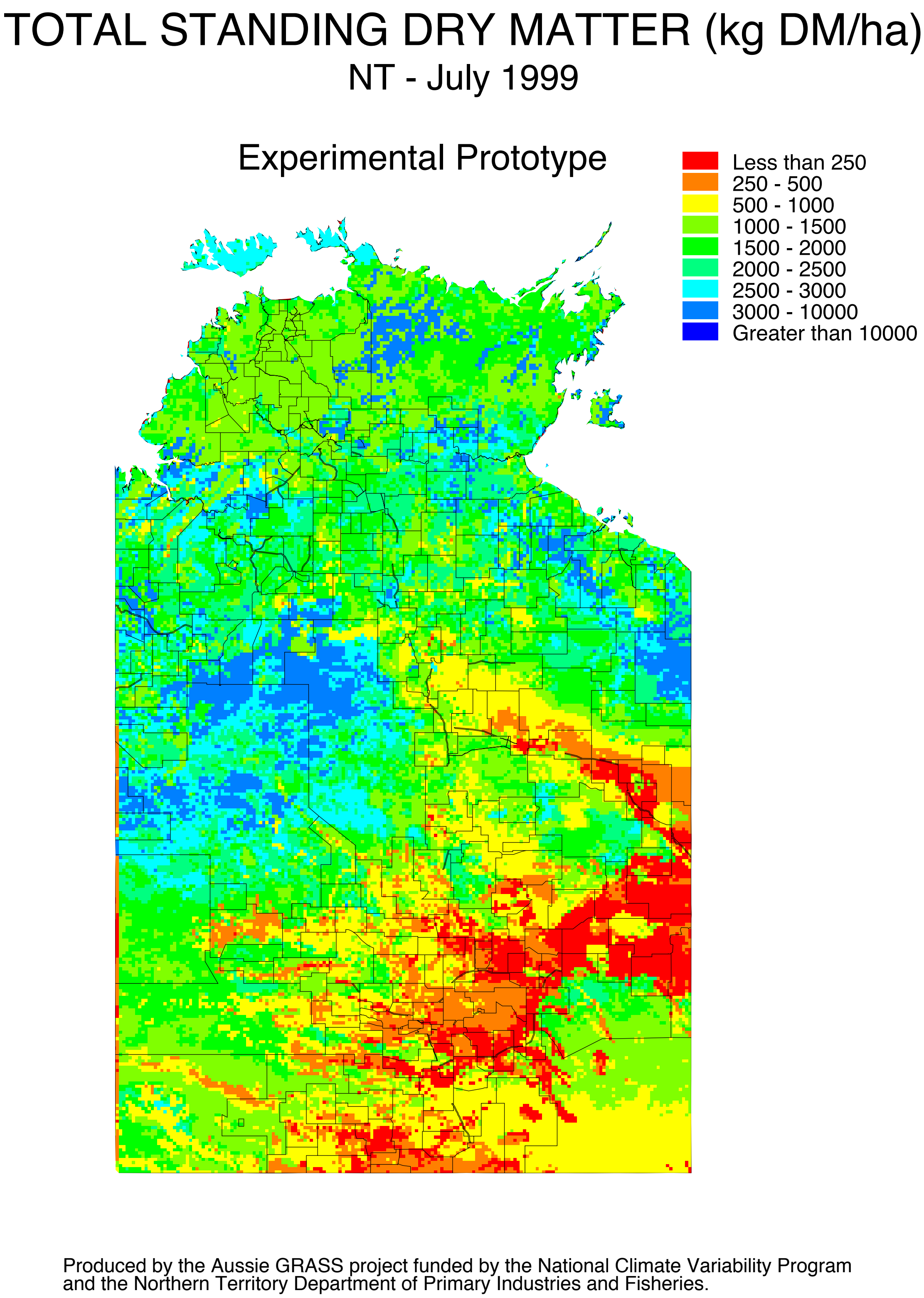


Figure 55. Simulated NT standing biomass map as at the end of July 1999.

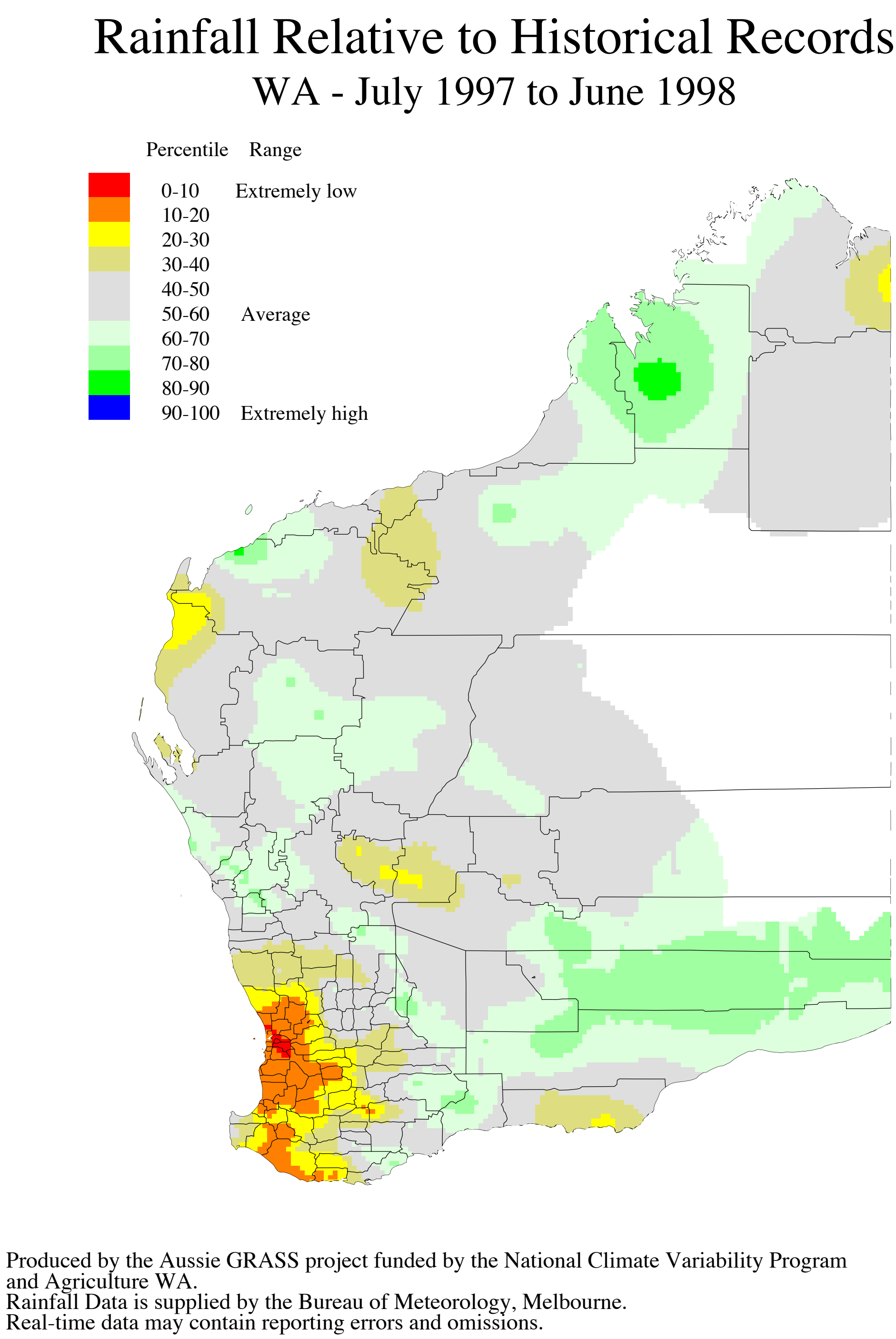


Figure 56. WA relative rainfall map for the 12-month period up to and including June 1998.

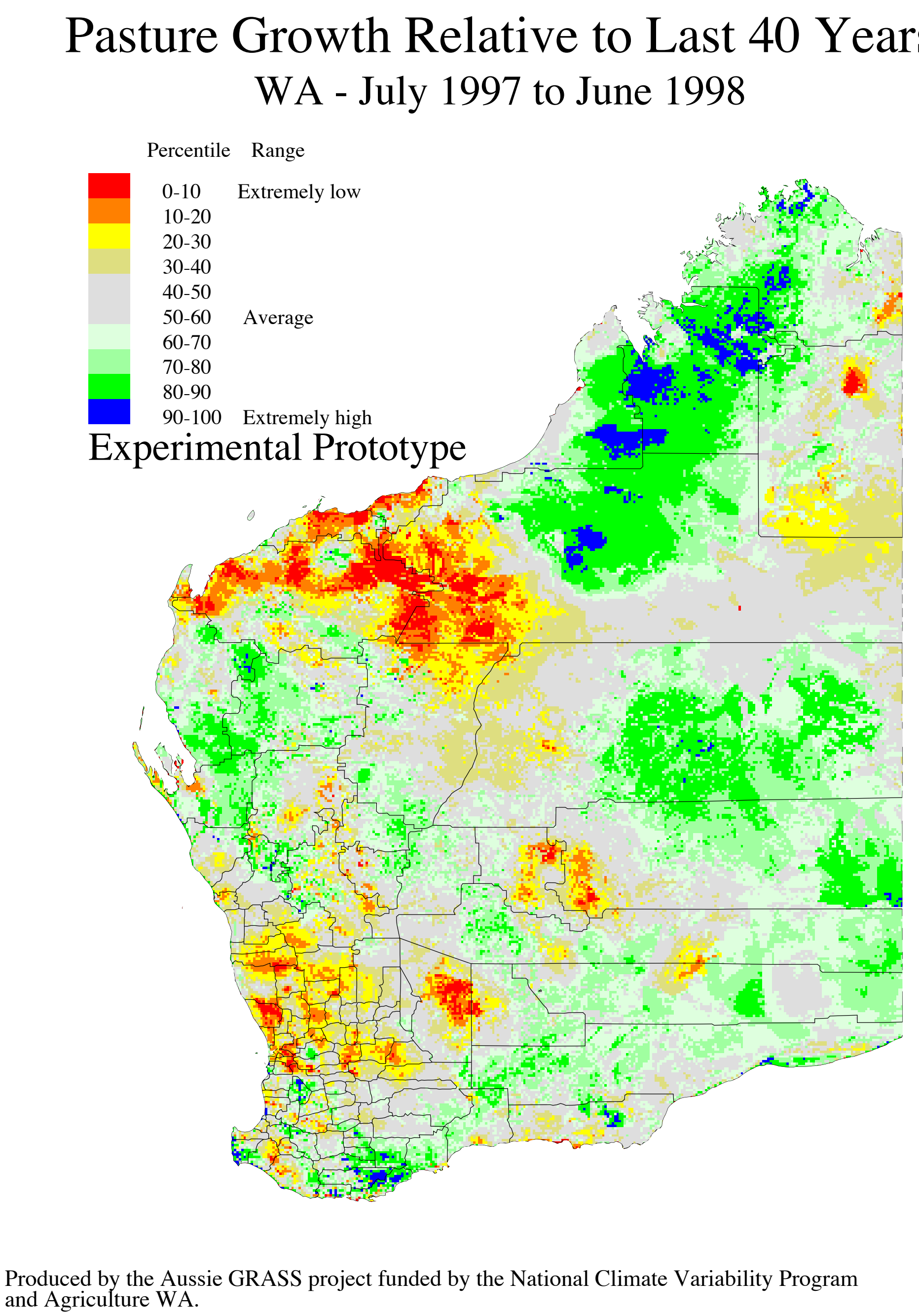


Figure 57. Simulated WA relative pasture growth map for the 12-month period up to and including June 1998.

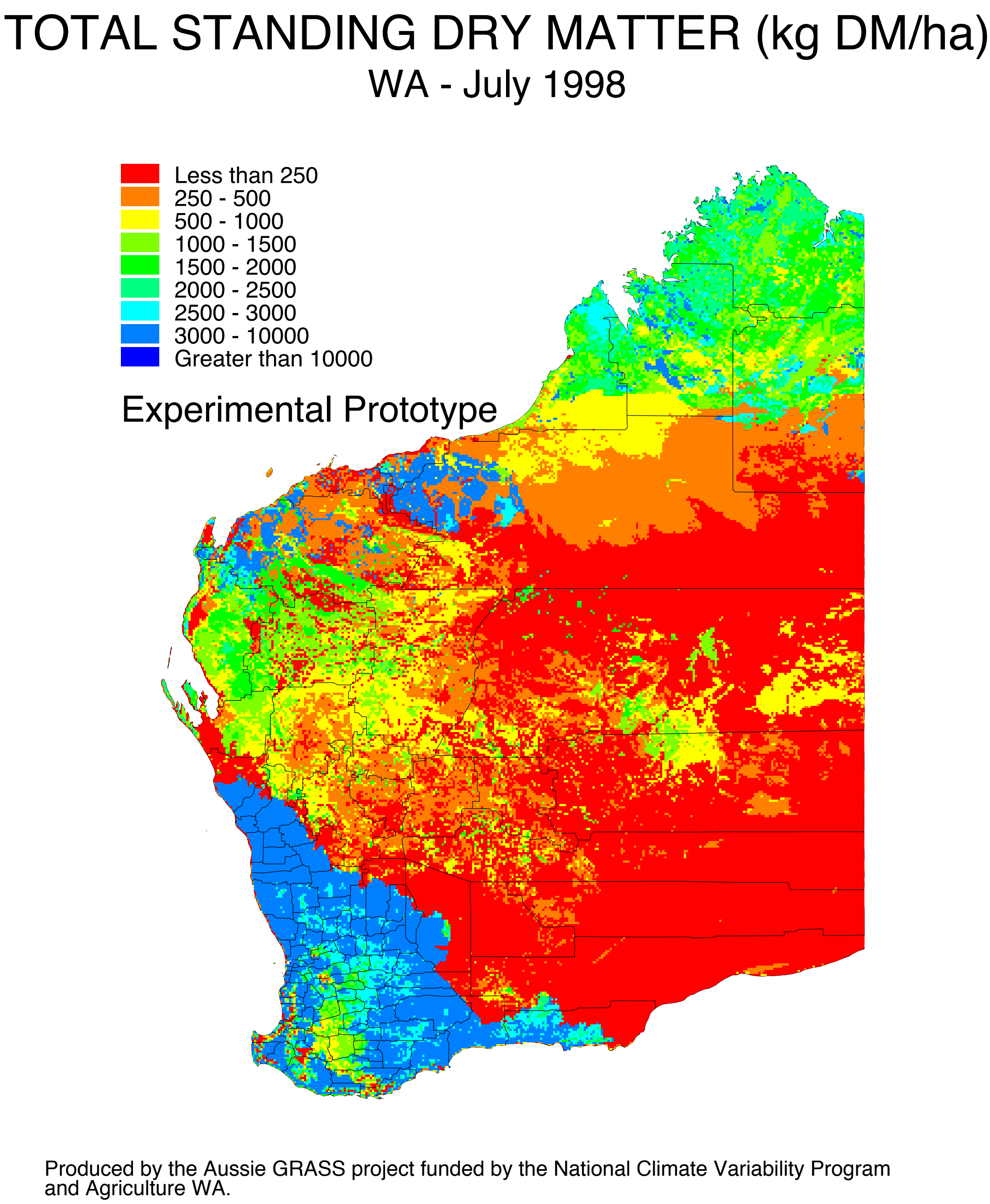


Figure 58. Simulated WA standing biomass map as at the end of July 1998.

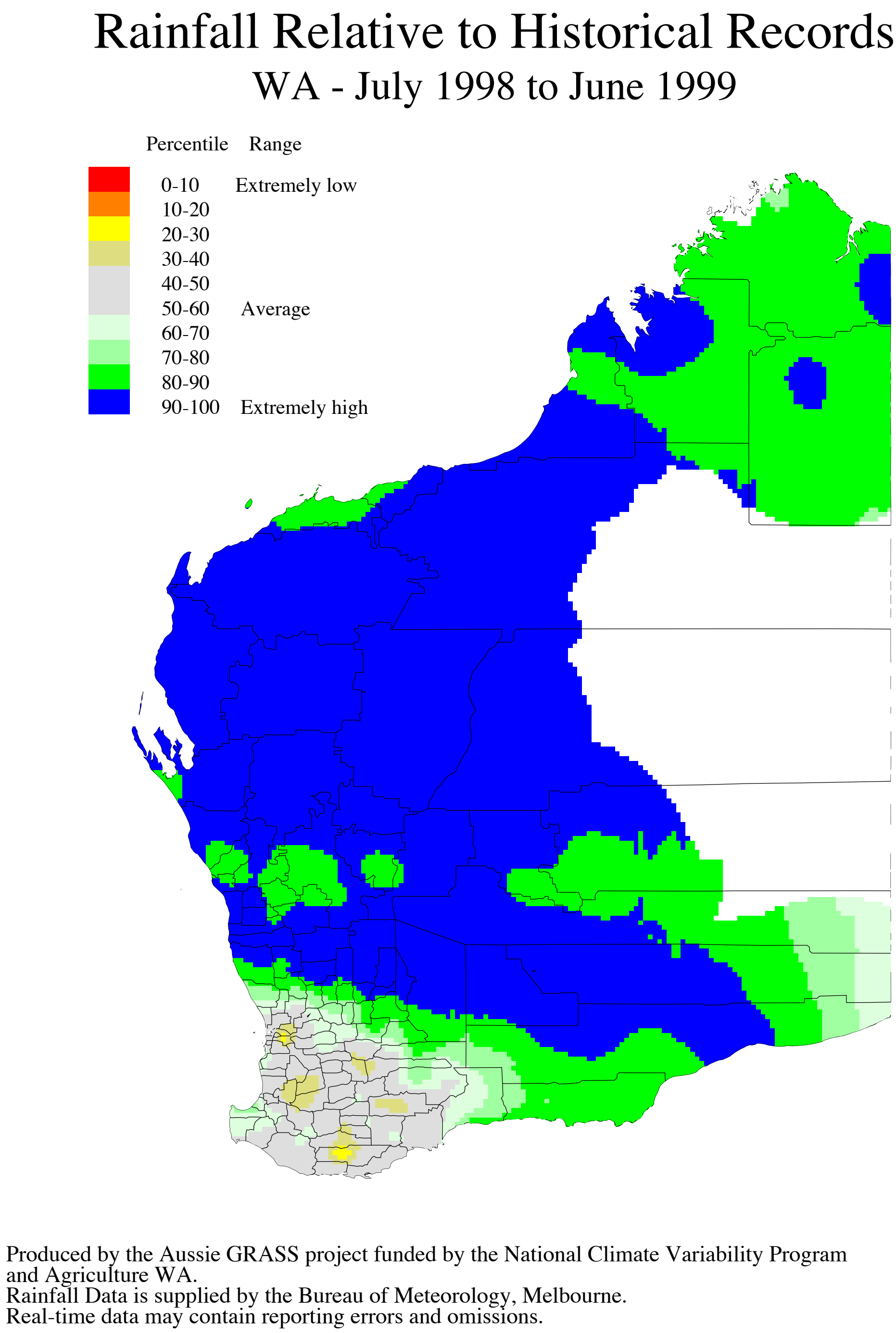


Figure 59. WA relative rainfall map for the 12-month period up to and including June 1999.

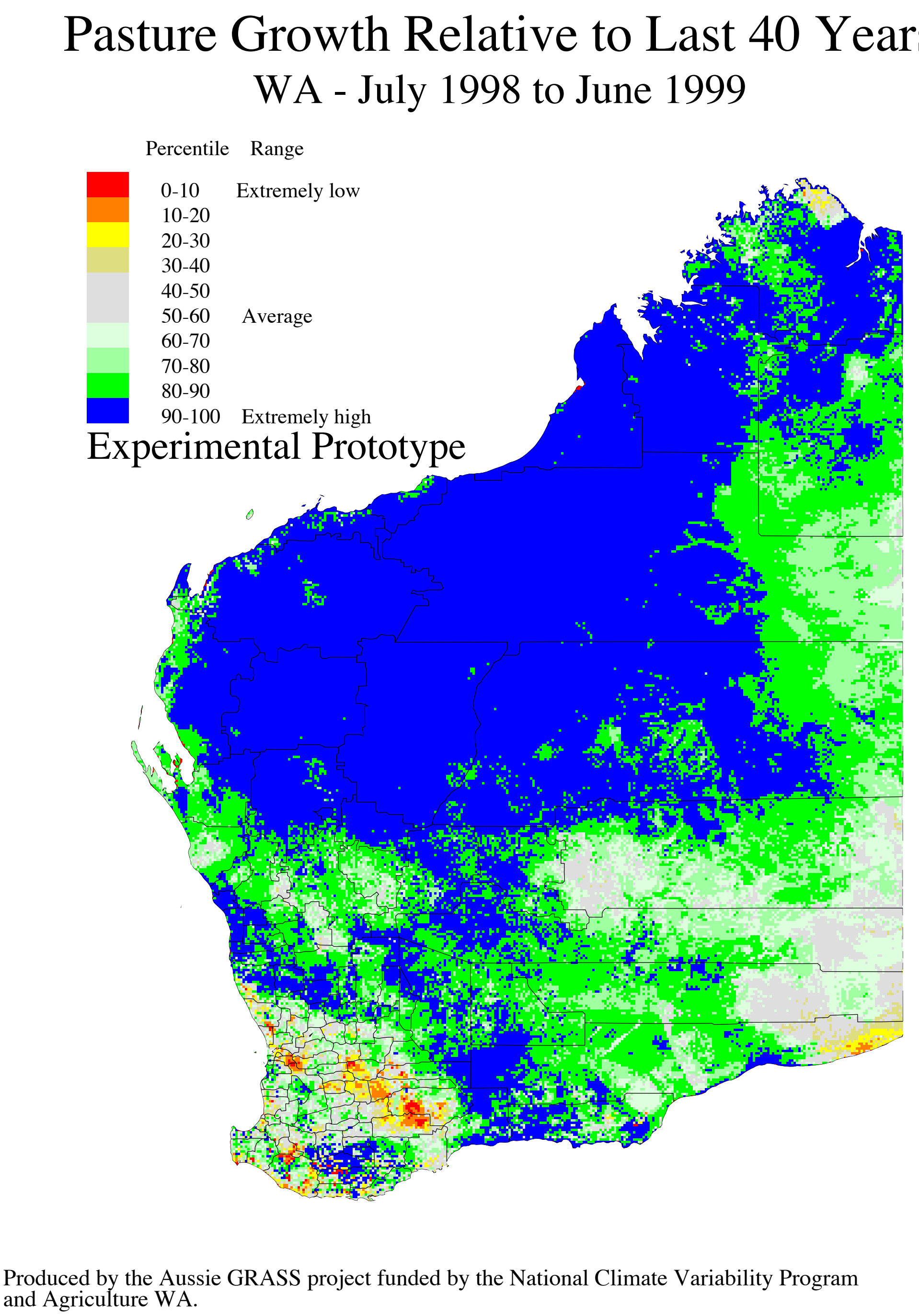


Figure 60. Simulated WA relative pasture growth map for the 12-month period up to and including June 1999.

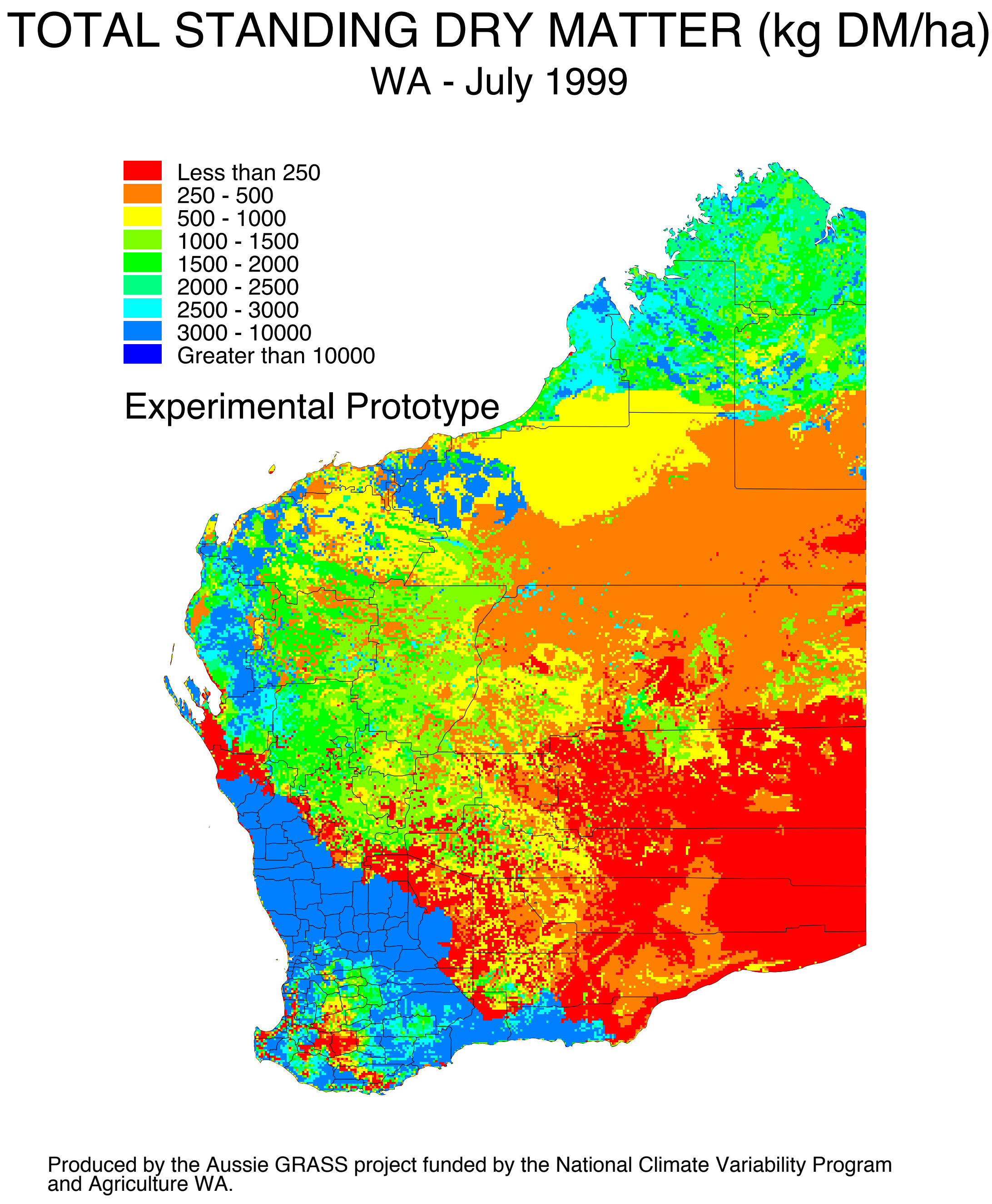


Figure 61. Simulated WA standing biomass map as at the end of July 1999.

8 Fire

Fire is an extensive and important influence across northern Australia. The accurate estimation of standing biomass by Aussie GRASS relies on the mapping of fire scars to provide a means of accounting for areas where standing biomass has been removed and yield can be reset to zero, or some appropriate value.

Currently the fire scar mapping of the Kimberley and NT is undertaken by the Western Australian Department of Lands and Administration (DOLA) under contract to the Tropical Savannas Cooperative Research Centre (CRC). An agreement has been made with the Tropical Savannas CRC which now provides the Aussie GRASS project direct access to fire scar imagery from DOLA. These images are automatically transferred from DOLA by NR&M, processed and then used in the monthly model runs to reset biomass to 200 kg DM/ha. This represents a major advance in modelling capability.

It has been recognised by agencies utilising remotely sensed National Oceanic and Atmospheric Administration (NOAA) fire scar imagery in northern Australia that ground truthing and an understanding of mapping error is necessary to improve the confidence and usefulness of the products. In September 1998 several agencies across northern Australia participated in a field exercise in the VRD to develop a method for ground truthing and testing the accuracy of NOAA fire scar imagery. Members from NTDPIF and NR&M were both involved in this exercise. Ground based and aerial data were collected throughout the district over a period of nine days and are currently being analysed.

The location of current season fire scars was recorded during all field surveys (Figures 62-64). In the NT, fire activity was greatest throughout the high rainfall non-pastoral lands of the Top End and Gulf where fuel loads were highest. The presence of fire scars decreased in southern arid regions, especially on pastoral land where fuel loads were very low. Fire scars recorded in 1999 were overlaid onto a fire scar map generated from remotely sensed NOAA satellite imagery (Department of Lands Administration, Western Australia) for the same year (Figure 65). There appears to be a reasonable match between observed and remotely sensed fire scars. Further collaborative work with the National Heritage Trust Sustainable Fire Management project is being undertaken to comprehensively assess the accuracy of remotely sensed NOAA fire scar products.

Fuel Curing Index and Potential Grassfire Risk are two new Aussie GRASS fire products of direct relevance to strategic fire management. Examples of these products for the NT and Kimberley (Figures 66-73) clearly display the spatial and temporal variations in fuel characteristics. The Curing Index is based on green and dead pool output from the model, while Grassfire Risk is determined from fuel load (TSDM) and curing index.

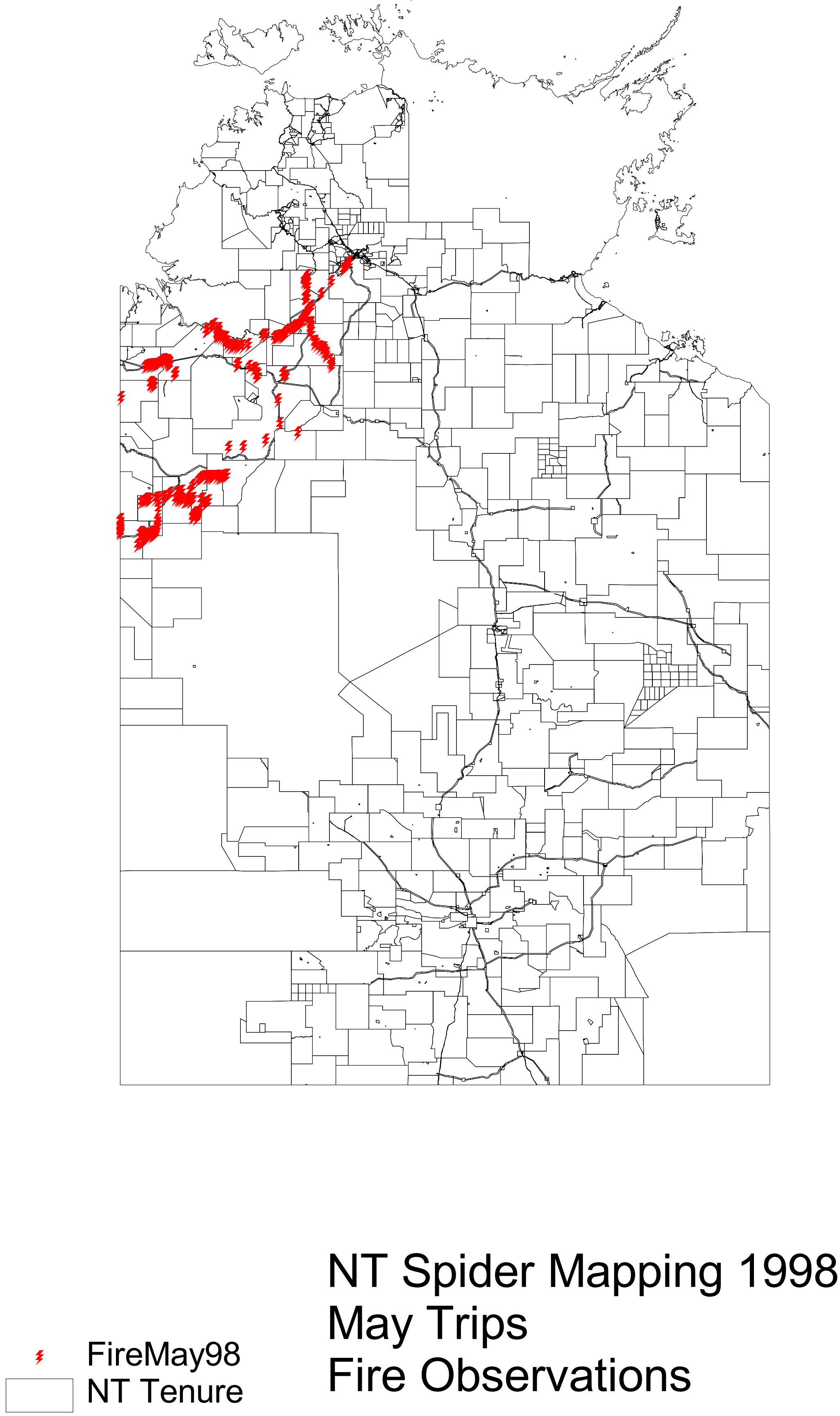


Figure 62. NT fire observations during May 1998 spider mapping trips.

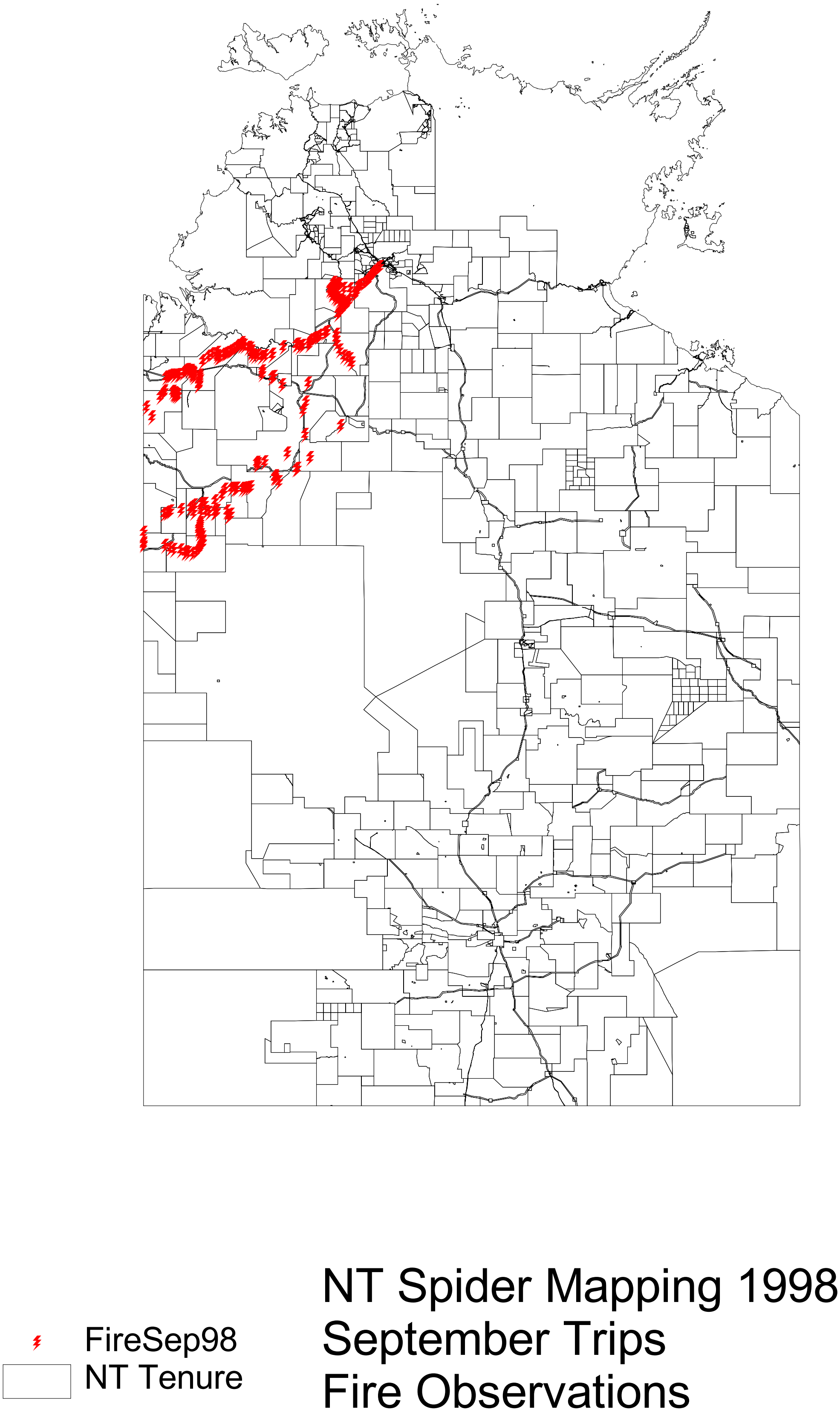


Figure 63. NT fire observations during September 1998 spider mapping trips.

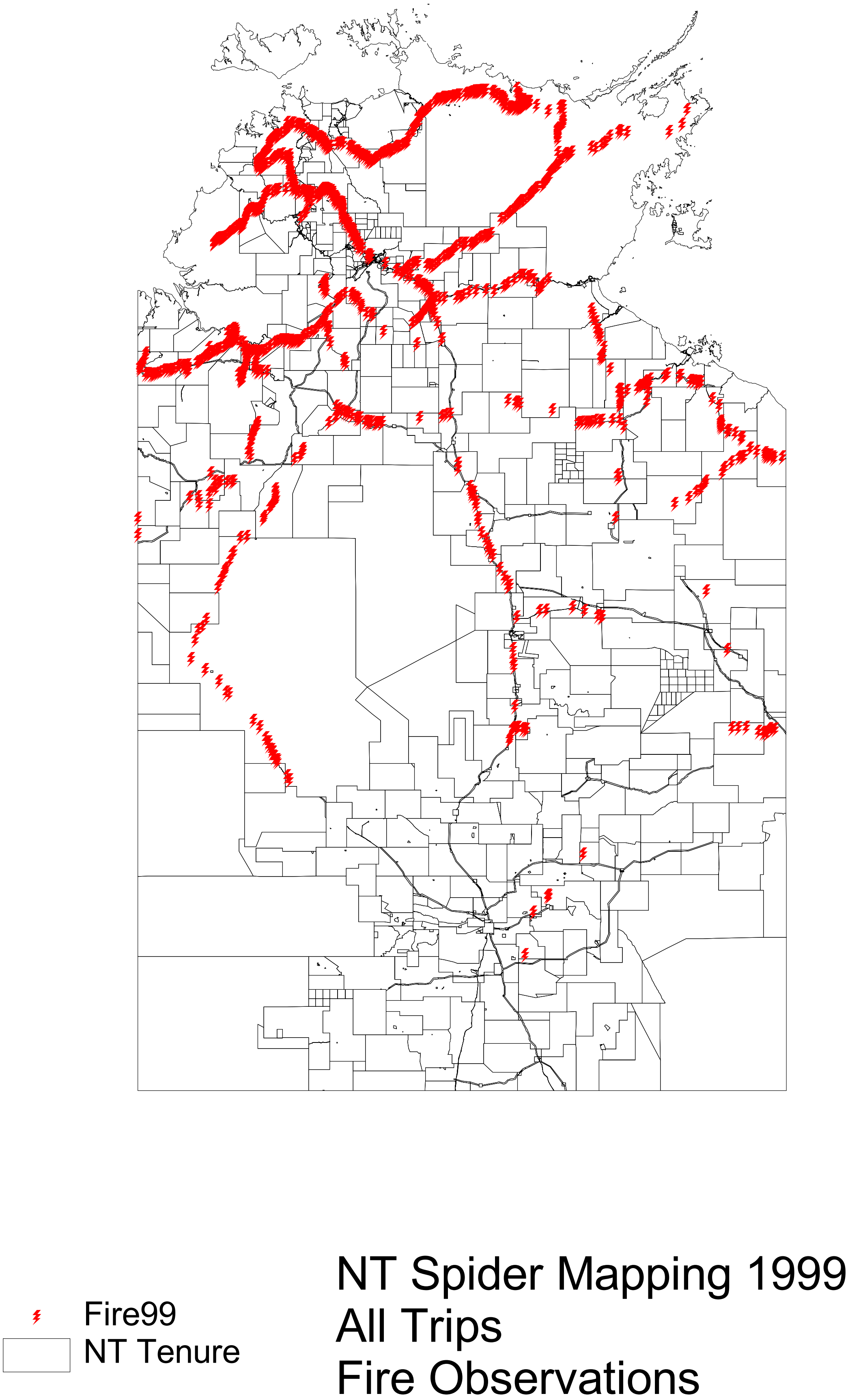


Figure 64. NT fire observations during 1999 spider mapping trips.

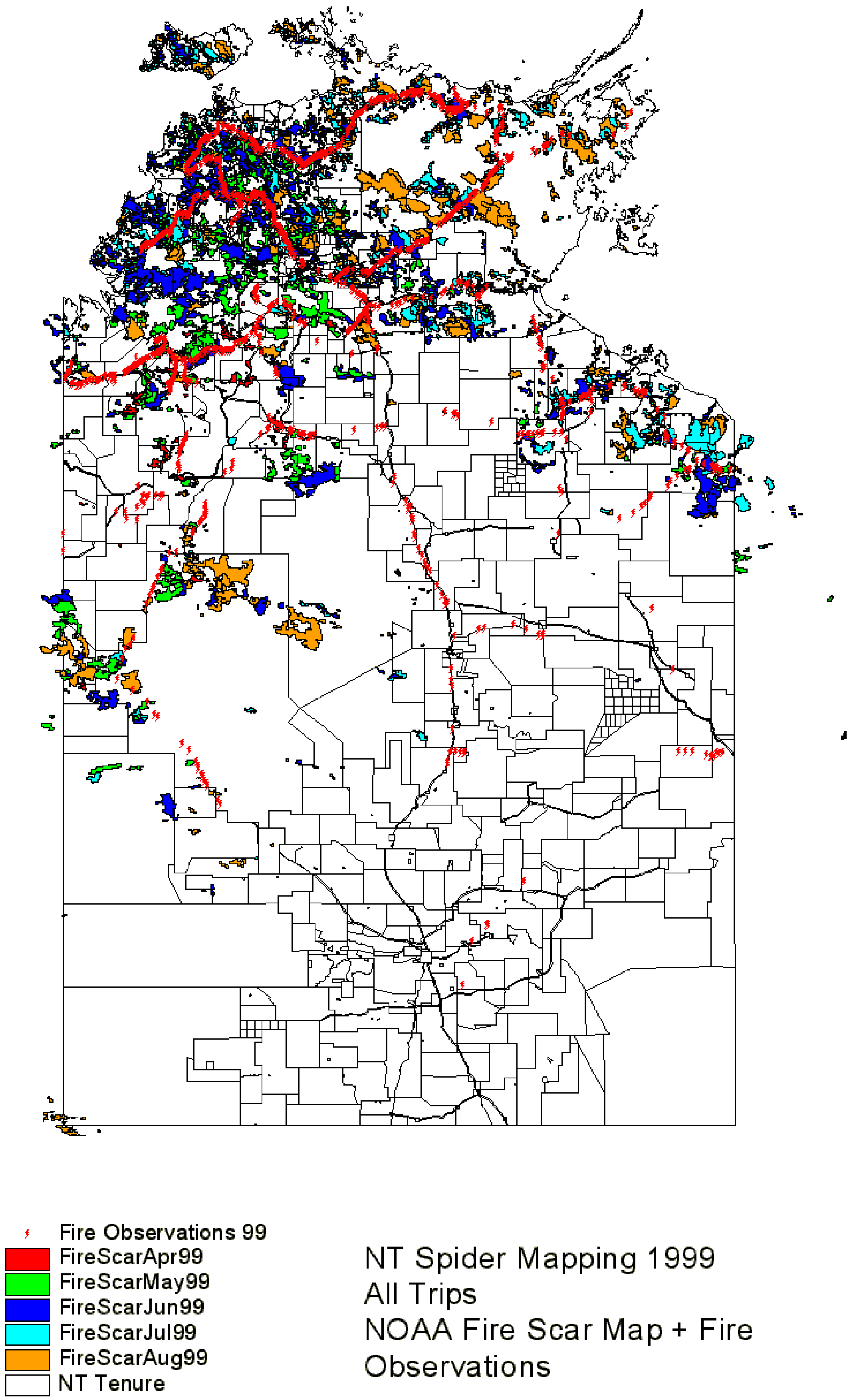


Figure 65. NT fire observations during 1999 spider mapping and satellite derived fire scars produced by the Department of Lands Administration, WA.

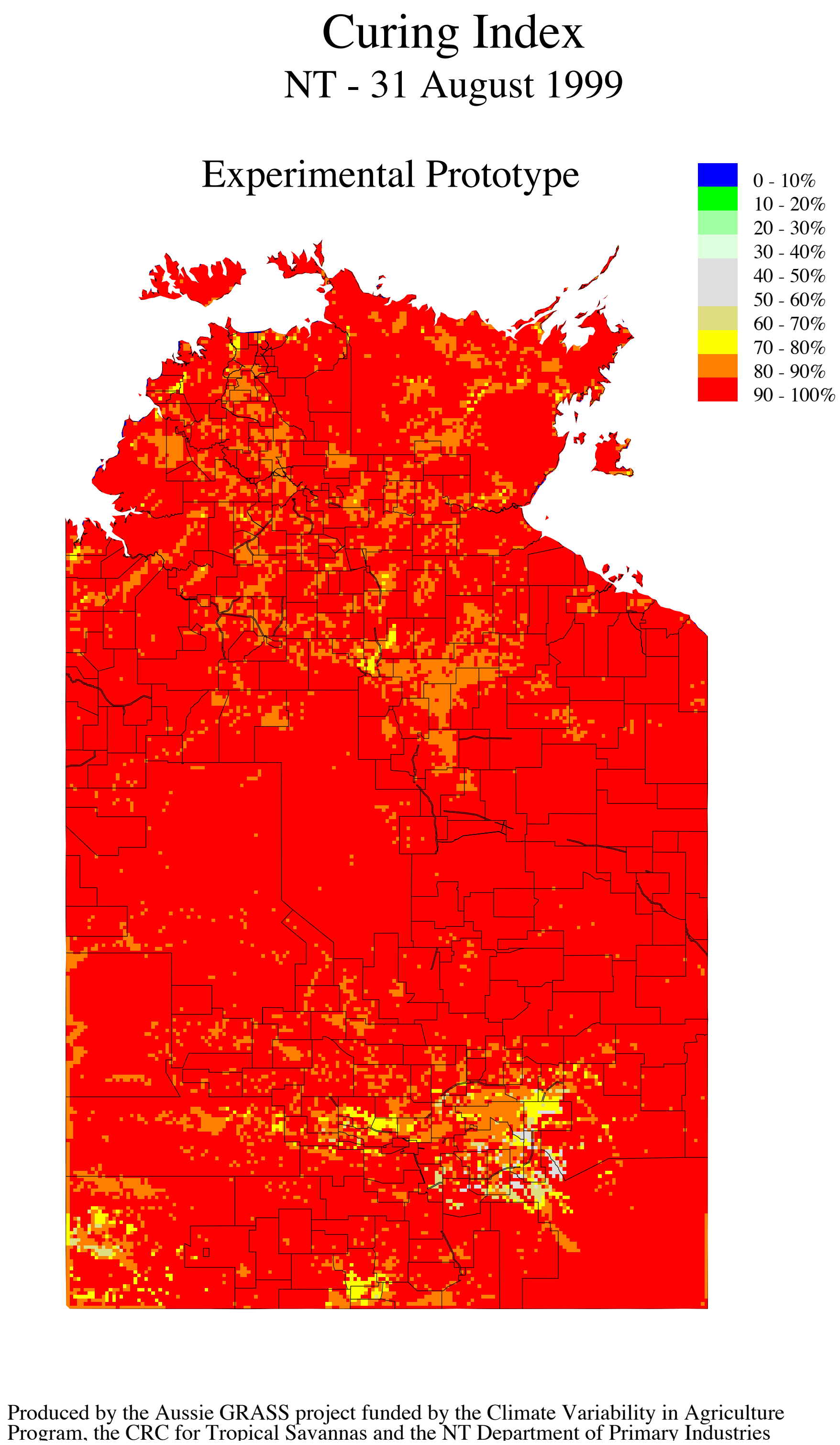


Figure 66. Simulated NT curing index map as at the end of August 1999.

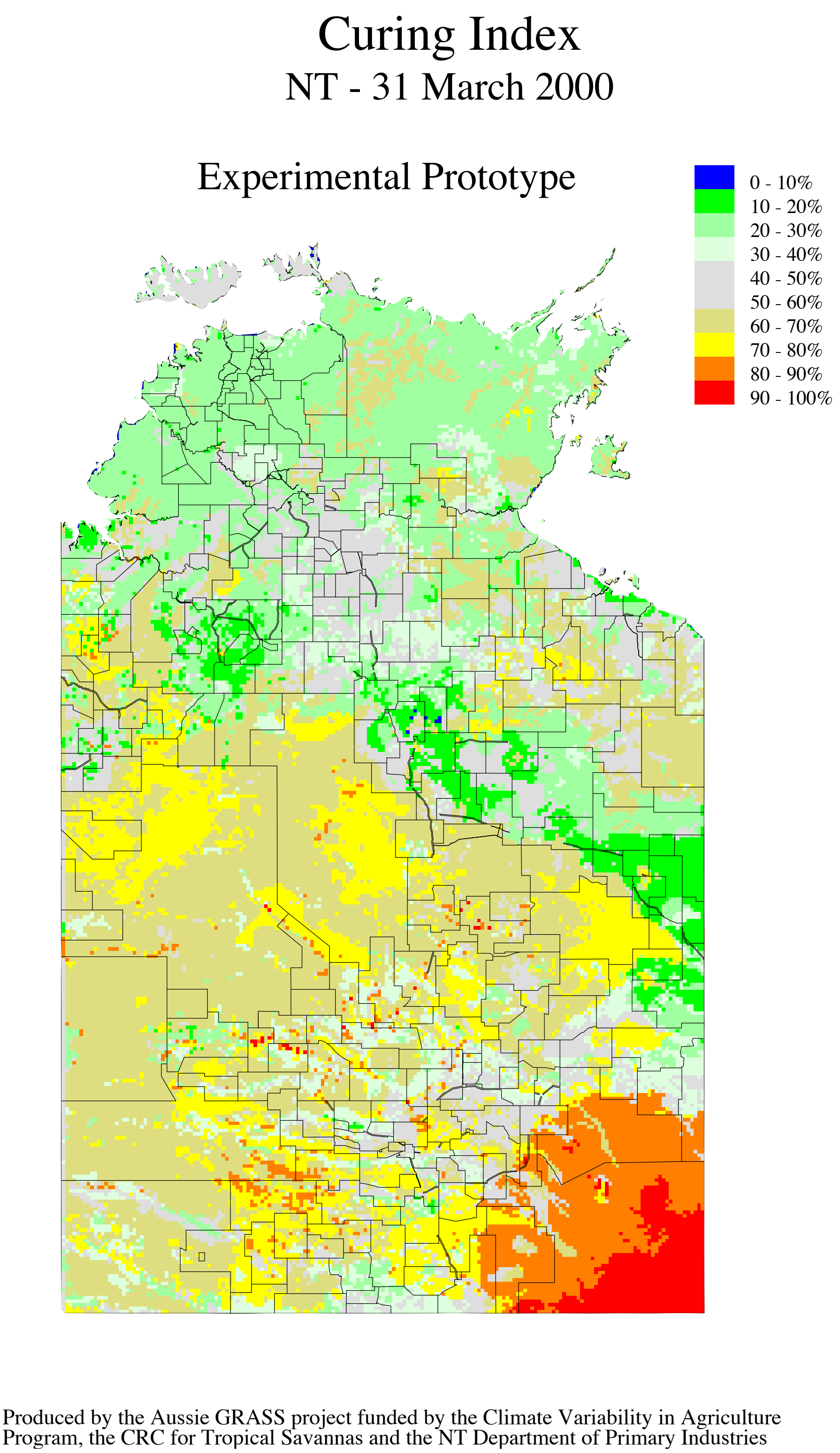


Figure 67. Simulated NT curing index map as at the end of March 2000.

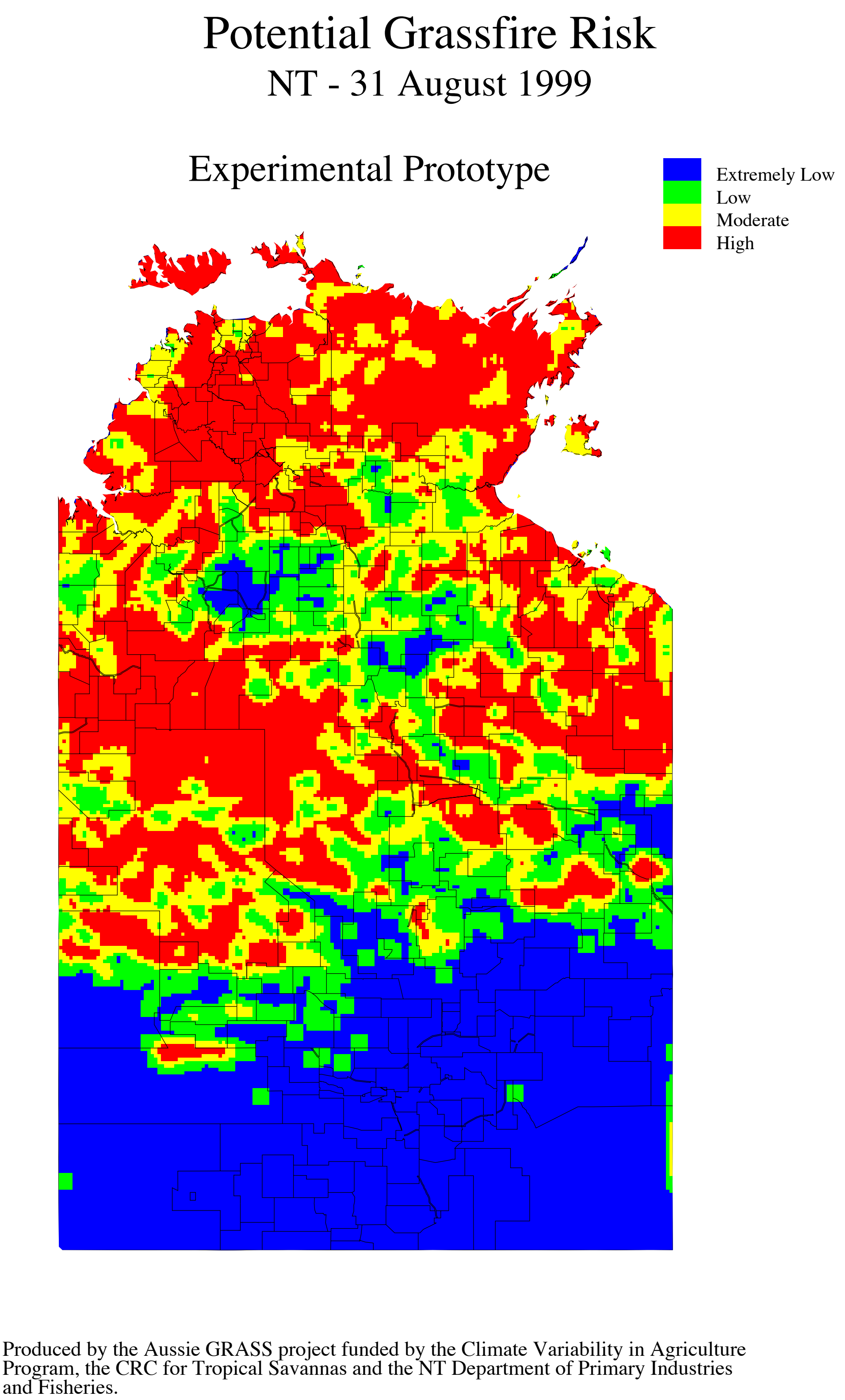


Figure 68. Simulated NT potential grassfire risk map as at the end of August 1999.

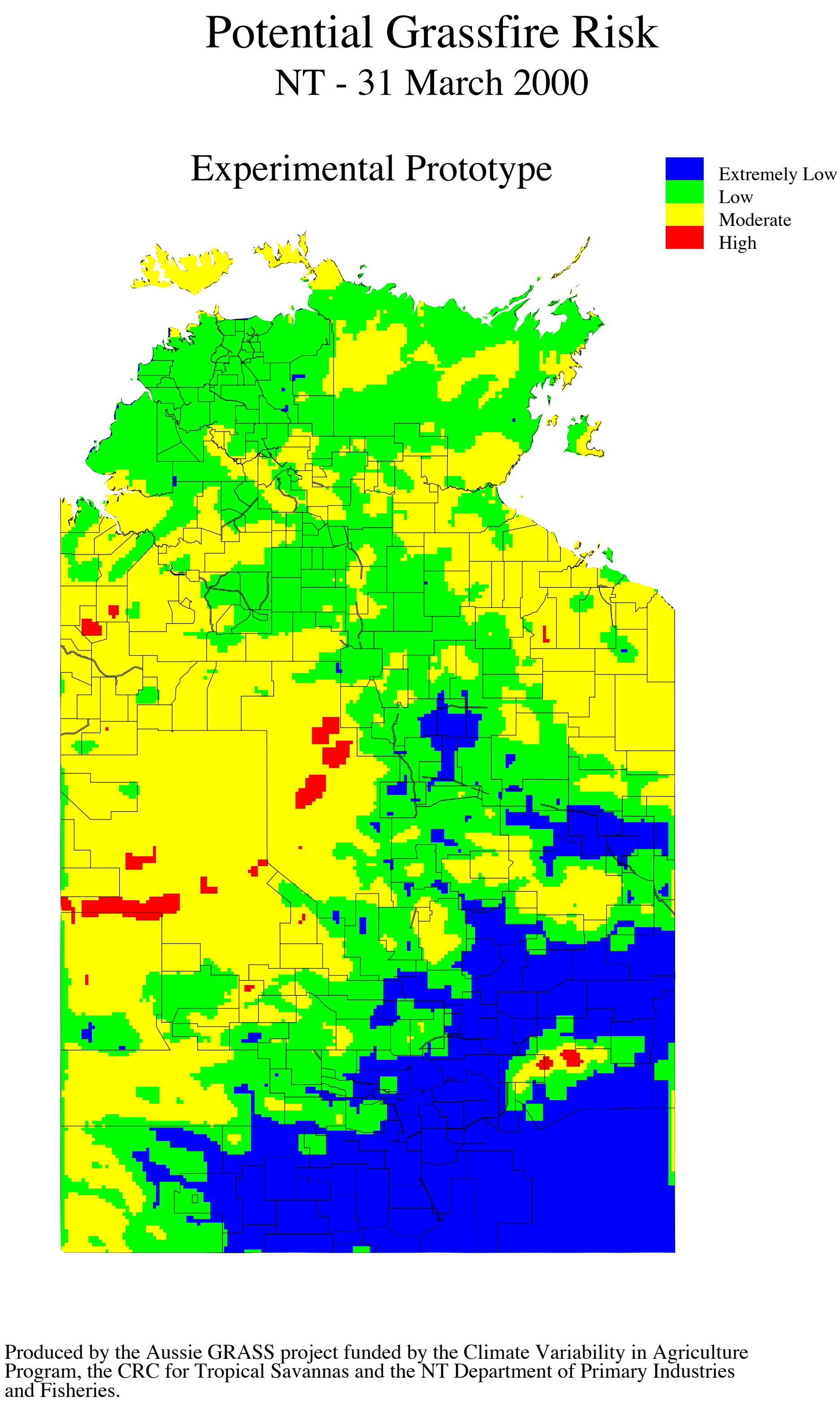


Figure 69. Simulated NT potential grassfire risk map as at the end of March 2000.

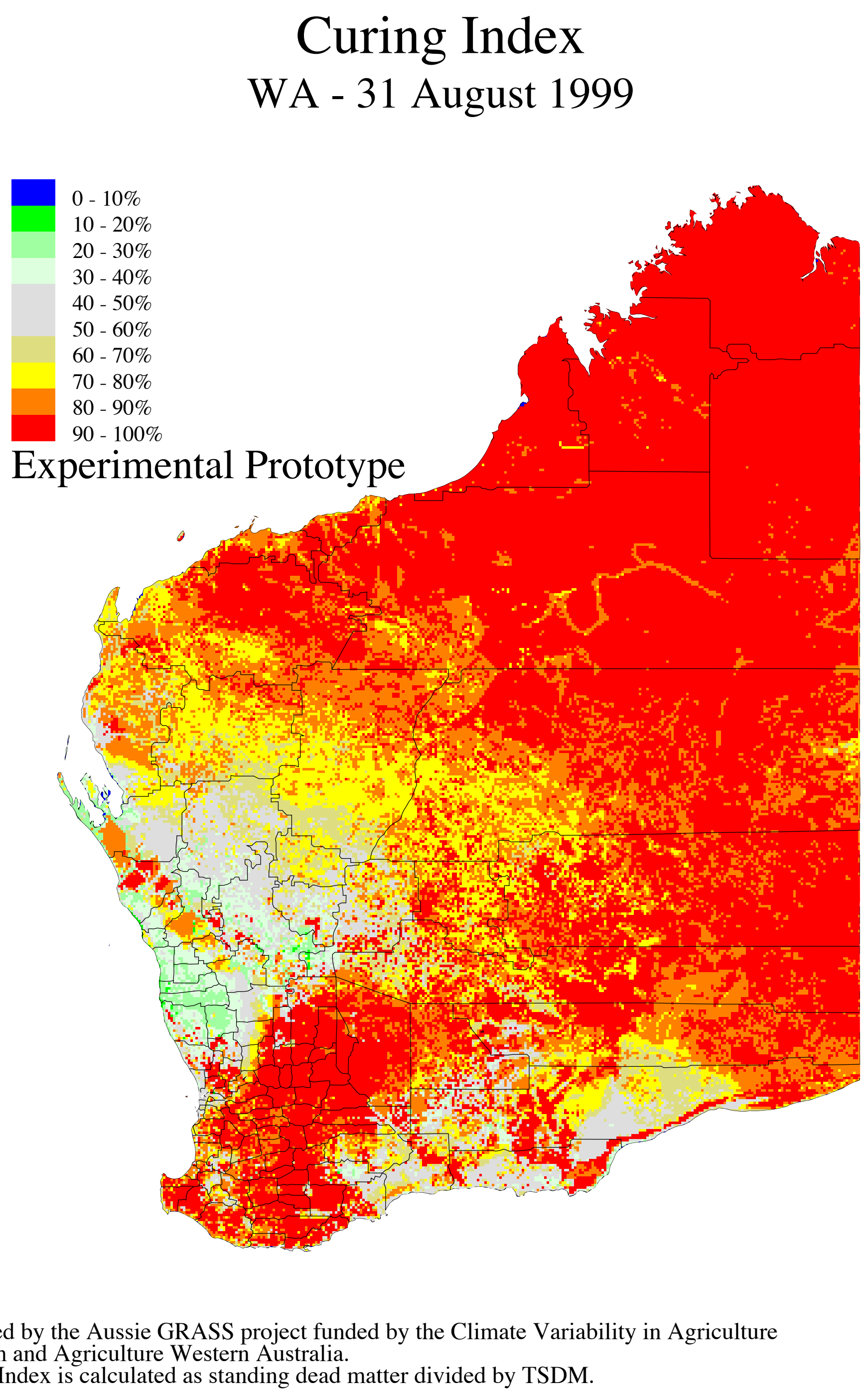


Figure 70. Simulated WA curing index map as at the end of August 1999.

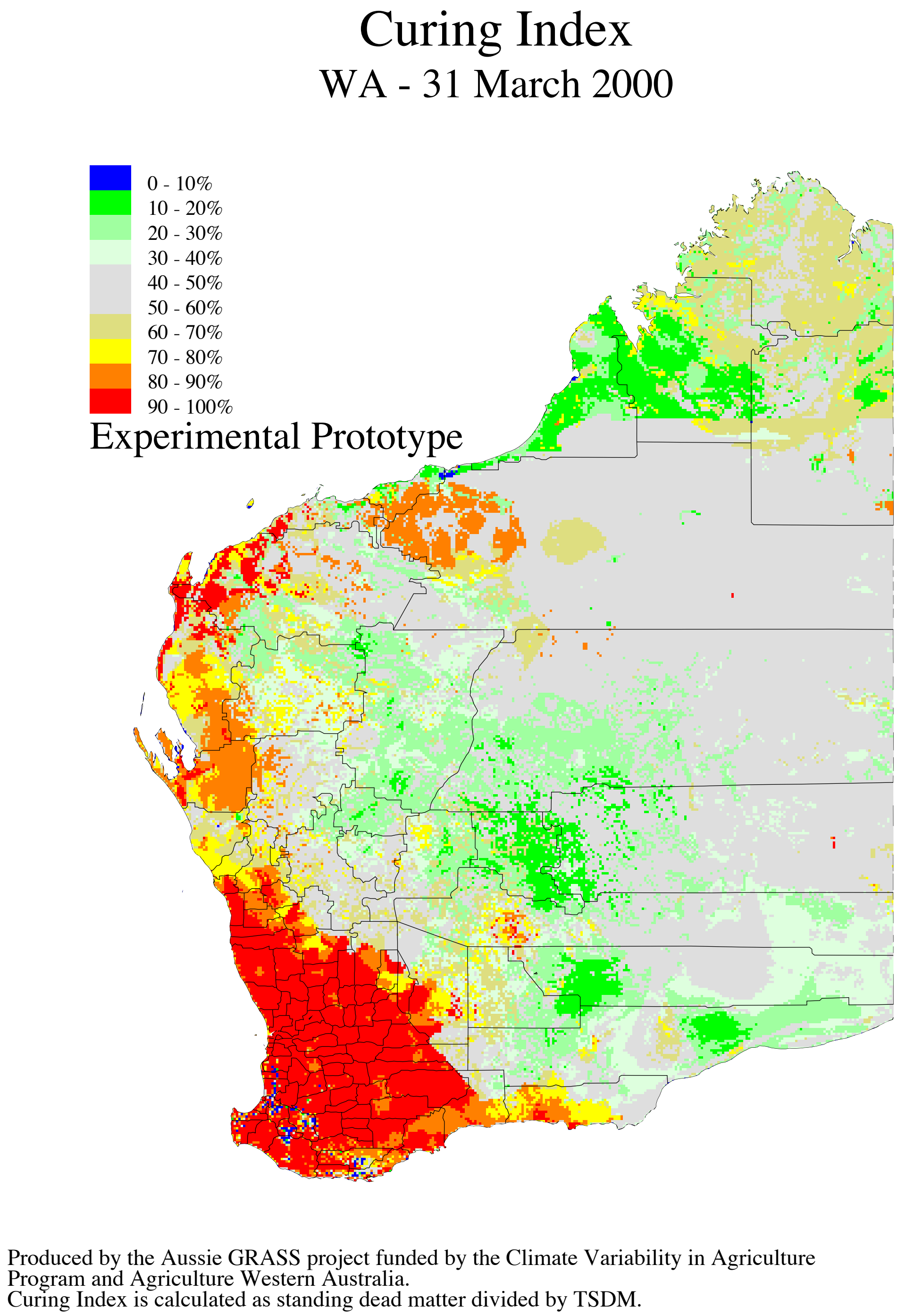


Figure 71. Simulated WA curing index map as at the end of March 2000.

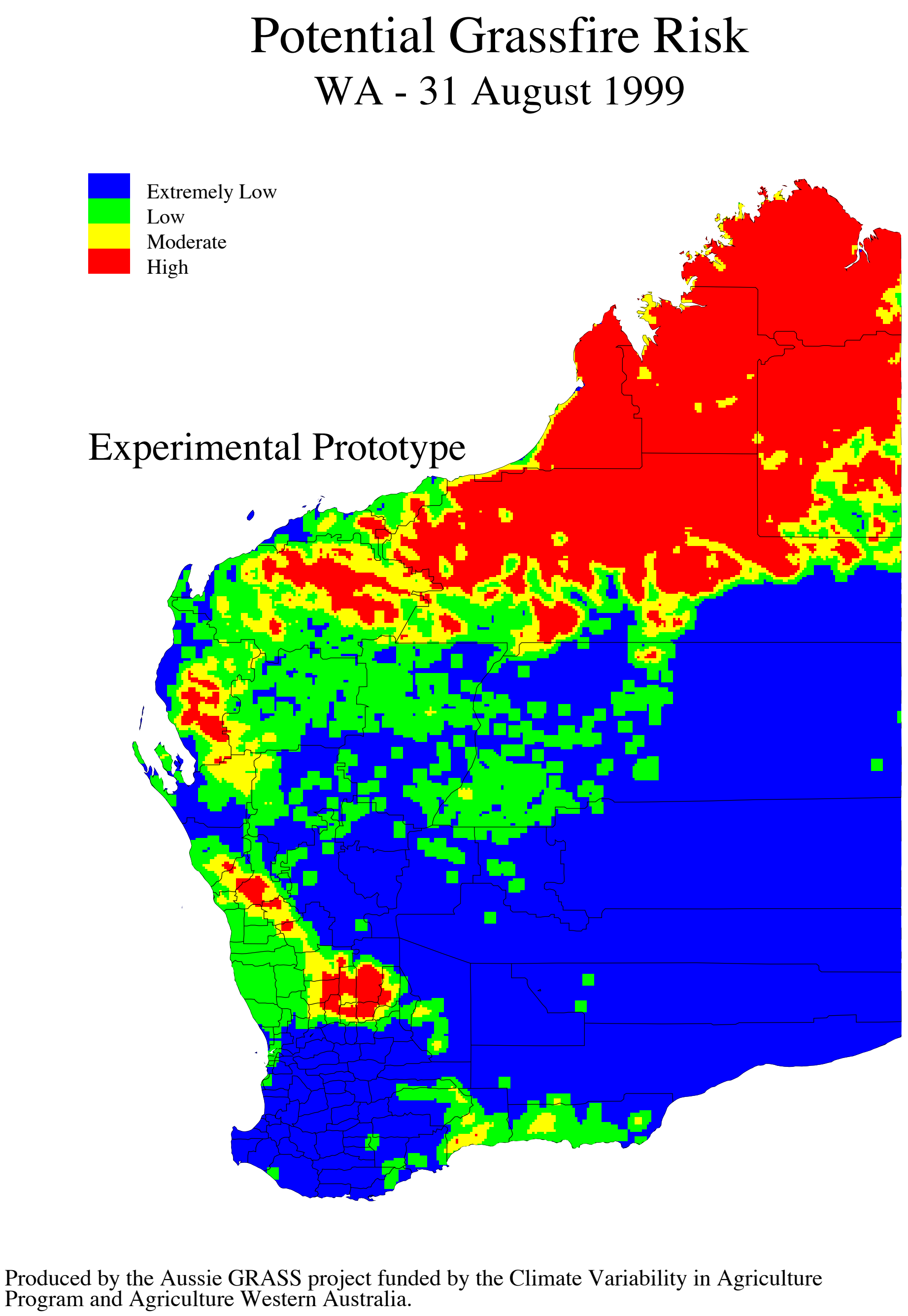


Figure 72. Simulated WA potential grassfire risk map as at the end of August 1999.

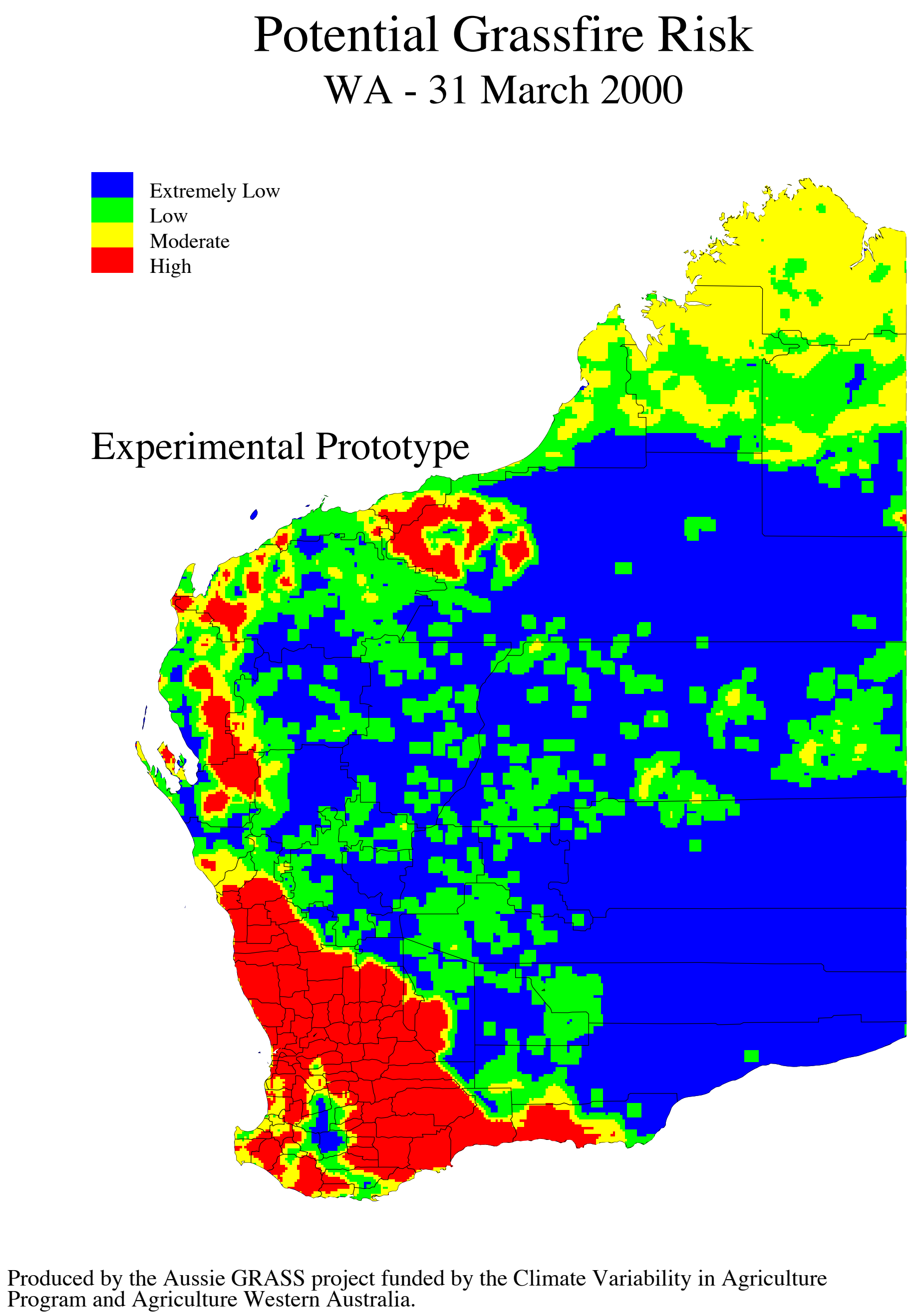


Figure 73. Simulated WA potential grassfire risk map as at the end of March 2000.

9 Spatial data

In the last couple of years the annual Australian Bureau of Statistics (ABS) agricultural census has been downgraded to a survey with a reduced number of properties sampled. In the NT, however, the government has provided additional funds to the ABS to maintain a full census. As a result the accuracy and resolution of ABS data collected for the NT and purchased by the Aussie grass project has been maintained. Investigation of the potential for direct recording of property stock data has shown that this approach is logistically impossible given the expected level of producer cooperation and available personnel and resources. A proposal by the Pastoral Land Board in the NT to require annual property stock returns from all pastoral stations provides hope for access to, and the inclusion into the model of accurate and current livestock density data.

The NT is currently involved in a National Land and Water Audit funded project which is reviewing all available vegetation mapping for northern Australia from which a single uniform product will be produced. This is currently not completed but when available will be used to replace the existing vegetation maps for northern Australia.

During property visits managers/owners were requested, where not already doing so, to consider joining the Bureau of Meteorology's (BoM) volunteer rainfall network. The proportion of land managers not already involved in the rainfall reporting network was very low, however a number did express an interest, and their details were subsequently passed on to BoM in Darwin for further action.

10 Product development

The NT and Kimberley Aussie GRASS personnel have been actively involved in the provision of feedback to NR&M as to the suitability of existing products to this region, and the requirement for modified and additional products to be available. This feedback has covered areas as simple as the scaling of legends used on products, through to comments from producers and staff on the accuracy of products, and addition of the NT cadastral pastoral boundaries as an overlay onto existing NT Aussie GRASS products.

11 Extension and communication

Training has been provided to Aussie GRASS personnel, associated research and extension officers, and producers through the provision of workshops by DPIF and QDPI in Alice Springs, Katherine and Kununurra. In addition, personnel have been extensively trained in the interpretation and use of products during reciprocal visits to QLD, NT and WA. These visits and workshops have enabled our own staff to become confident in the ability to extend the products. Extension opportunities have included field days, industry newsletters and radio interviews, but most importantly, one-on-one interaction with owner/managers as part of the many property visits.

A range of activities were undertaken during the project including:

- Aussie GRASS workshops in Katherine and Alice Springs;

- Katherine MLA Meat Profit Day, 8th April 1999 (350 people);
- Spider mapping training meeting, Kidman Springs, NR&M, NTDPIF and AGWEST, March 1998 and 1999;
- Interview ABC NT Country Hour, April 1999;
- Katherine Farm and Garden Day, April 1999 (1200 people);
- Presentation to Bushfires Council of the NT, Annual Meeting 1998, 2000;
- Promotion of products and project to land managers during property visits;
- Heytesbury Pastoral Group workshop, May 2000; and
- Presentation at Kidman Springs Field Day, April 2000.

12 Conclusions and the future

The integration of growth parameters from generic pasture models and the collection of large biomass data sets during extensive spider mapping has enabled further development and calibration of spatial models throughout the NT and Kimberley. This has significantly increased the level of relevance and confidence in model outputs.

The provision of near real-time seasonal condition reports, land condition alerts and utilisation products has been identified as a priority for both the NT pastoral industry and government agencies. Strong support exists for continued access to and development of Aussie GRASS products. Government agencies who have indicated interest in access to Aussie GRASS products include the NTDPIF, Agriculture Western Australia, Department of Land, Planning and Environment, Pastoral Land Board, Northern Territory Parks and Wildlife Commission, and the Northern Territory Bush Fire Council.

The production of a monthly seasonal condition report for the NT, as currently exists in Queensland, is seen as a priority. One pastoral company has noted the potential for Aussie GRASS as a strategic planning and early warning tool for managing carrying capacity. It has also been proposed that Aussie GRASS be assessed to provide a source of seasonal land condition information for NT monitoring responsibilities. To this end, a range of seasonal condition assessment tools, including Aussie GRASS, will be examined and the possibility of incorporating them is being discussed by government agencies.

Although existing Aussie GRASS output and products are adequate for the NT in terms of accuracy, further calibration, validation and product development should occur in the NT and in other States to maximise reliability and usefulness. This is particularly important for vegetation communities such as annual sorghum and spinifex pastures that have not been represented by SWIFTSYND sites, which provide detailed growth parameters. A proposal within the NT of a multi-departmental, multi-product, monitoring group has been raised. Government agencies are being approached with the proposal of each contributing sufficient funds over a three-year period to provide support for continued model outputs. This proposal hopes to raise a total of $70,000 pa, allowing further model development to continue.

13 Appendix 1: Aussie GRASS parameters for the Victoria River District, Northern Territory, based on SWIFTSYND data

Ken Day, Michael Cobiac and Rodd Dyer

13.1 Introduction

Parameters for the Aussie GRASS spatial model are required for broad land types which can be readily mapped at a continental scale. A single parameter set for the entire Victoria River District (VRD, Figure A1) may be sufficient for purposes of drought analysis which involves ranking year types. However, for other purposes, e.g. calculating safe carrying capacity, differences in productivity between land types become more important. Productive grazing lands of the VRD can be readily classified and mapped on the basis of soil type (e.g. Stewart *et al*. 1970). A field study was established in 1993 as part of the MRC funded project 'Developing sustainable beef production systems for the semi-arid tropics of the Northern Territory', which aimed to determine pasture model parameters for major productive land types of the VRD and for various pasture condition states. The GRASP model was calibrated to the twenty-one SWIFTSYND sites (Day and Philp 1997) established in that experiment (K. Day unpublished). For the Aussie GRASS project, this data has been used to generate model parameters at the land systems and soil type levels (Table A1). Model estimates of biomass based on these general parameter sets were then compared with SWIFTSYND biomass observations at the beginning of the dry season. The data used to validate the model were the same as those used to calibrate the model so further independent validation of the model parameters is still required to confirm the generality of the various parameter sets.

13.2 Field measurements

Twenty-one SWIFTSYND sites were established on five properties (Mt Sanford, Victoria River Downs, Rosewood Station, Kidman Springs and Auvergne Station) in the VRD (Figure A1). Sites were subjectively selected on the basis of soil type and pasture composition by two of the authors (R. Dyer and M. Cobiac) and, at the time of establishment (1993 and 1994), were considered to be representative of a range of condition states within important productive land types of the VRD (Table A1). Sward and soil measurements were made on each of the 21 sites according to the SWIFTSYND method (Day and Philp 1997). Each site was sampled for two consecutive years with measurements on all sites conducted within a three-year period (1993 to 1996). Sites were either mown or burnt in the late dry season of each year and harvests were subsequently conducted in the early wet season (December, January), mid wet season (February, March), early dry season (May, June), and late dry season (October, November). Detailed description of these sites and field measurements are reported elsewhere (M. Cobiac's Masters thesis in prep.).

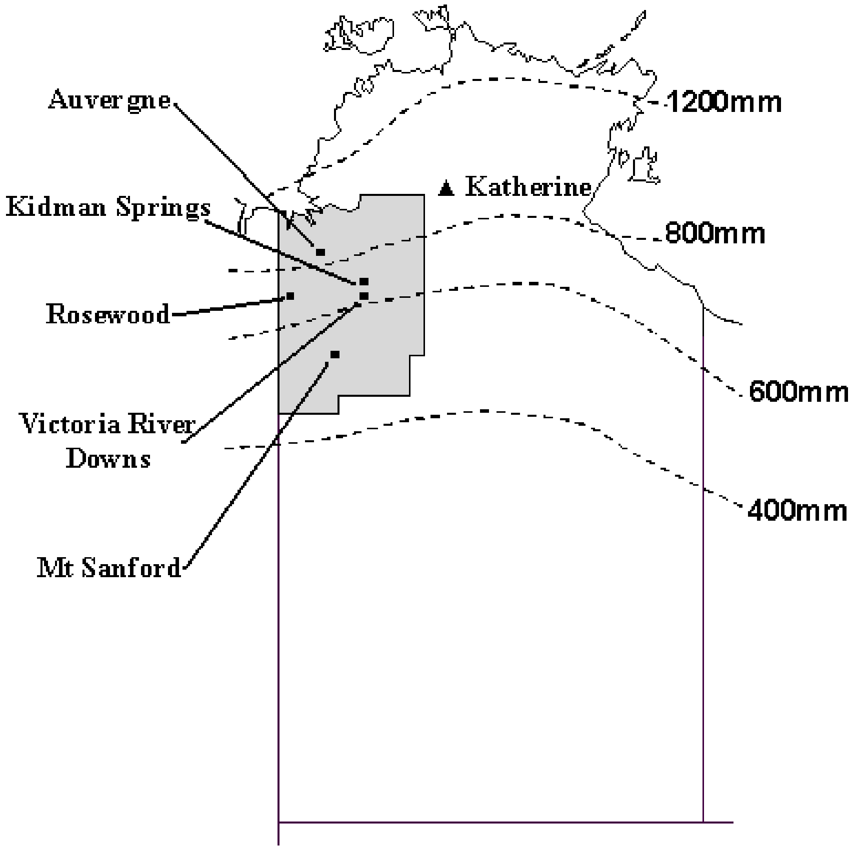


Figure A1. Location of properties with SWIFTSYND sites in the VRD.

Table A1. Land systems (Stewart *et al.* 1970) and soil types for the 21 SWIFTSYND sites in the VRD.

Soil Group	Land system	Location	No. sites	No. site x years with typical species
Structured basaltic red earth	Antrim	Mt Sanford	2	2
		Rosewood	1	0
Structured calcareous red earth	Humbert	Kidman Springs	2	2
	Dinnabung	Kidman Springs	2	2
Alluvial grey cracking clay	Argyle	Kidman Springs	4	6
	Ivanhoe	Victoria River Downs	2	2
		Auvergne	2	4
Basaltic black cracking clay	Wavehill	Mt Sanford	4	8
		Rosewood	2	4

13.3 Model calibration

The GRASP model was calibrated independently for each site based on measurements from all harvests (K. Day unpublished). Measurements considered in the calibration process included soil water and sward attributes (biomass, cover, height, nitrogen concentration and nitrogen uptake). The aim of the model calibration was to derive a single set of soil parameters for each site and measurement year. However, in the case of three sites, a parameter relating sward cover to sward biomass was altered in mid-season based on observed changes in the ratio of sward cover to sward biomass. This change in sward structure is attributed to a shift from forb dominance early in the wet season to grass dominance later in the wet season.

Calculations from the calibrated model were in close agreement (r^2=0.93) with observed sward biomass (Table A2, Figure A2) and soil water (r^2=0.87, Figure A3) for all harvests. Although the model was closely calibrated to the observed data, such a close agreement between observed data and model calculations provides little indication of the predictive capacity of the model. The close fit between observed and calculated biomass during the early and late dry season (r^2=0.97 in both cases, Table A2) is due to the calibration process, as follows. At the beginning of the dry season sward biomass is closely governed by potential nitrogen uptake and the nitrogen concentration at which pasture growth stops. These factors are explicitly calibrated in GRASP based on observations at this time of year. At the end of the dry season sward biomass is closely governed by: 1) biomass at the end of the growing season (considered above); and 2) detachment rate. If maximum biomass was attained by the end of the wet season, which was most often the case, the calibration of the detachment rate parameter in GRASP was based simply on the observed rate of change in biomass between the beginning and end of the dry season. Hence close agreement between observed and calculated biomass is expected at the end of the dry season.

Table A2. Coefficient of Determination (r^2) between observed and simulated pasture biomass for SWIFTSYND sites across the VRD (21 sites x 2 years x 4 harvests/year). Model calculations are based on parameters calibrated to the SWIFTSYND data for individual sites and years.

Early wet season	Mid wet season	Early dry season	Late dry season	All harvests
0.60	0.77	0.97	0.97	0.93

13.3.1 Deriving general parameters for the VRD

Parameters were averaged across years for each site and the resultant site parameters were then averaged according to land system (Table A1). Land system parameters were then further averaged according to major soil types (Table A1). All sites were considered in determining average soil parameters (i.e. parameters defining plant available water range). However, only selected sites for which the species composition was typical of the broader land system were considered in determining average plant parameters (Table A1). In this regard species composition of the following sites were considered atypical of the land system as a whole: Antrim (Site 1 - second year, Site 2 - second year, Site 19); Argyle (Site 7); Humbert (Site 13); Dinnabung (Site 14); and Ivanhoe (Site 15). Aggregated parameters for land systems and soil types are listed in Table A3.

An average VRD parameter set (Table A3) was also determined by averaging soil and plant parameters across all 42 site x year combinations. The averaging process ignored parameter changes within years that were attributed to transient shifts in species composition. In Table A3 the average VRD parameters are contrasted with average parameters independently derived for Queensland (Day *et al.* 1997).

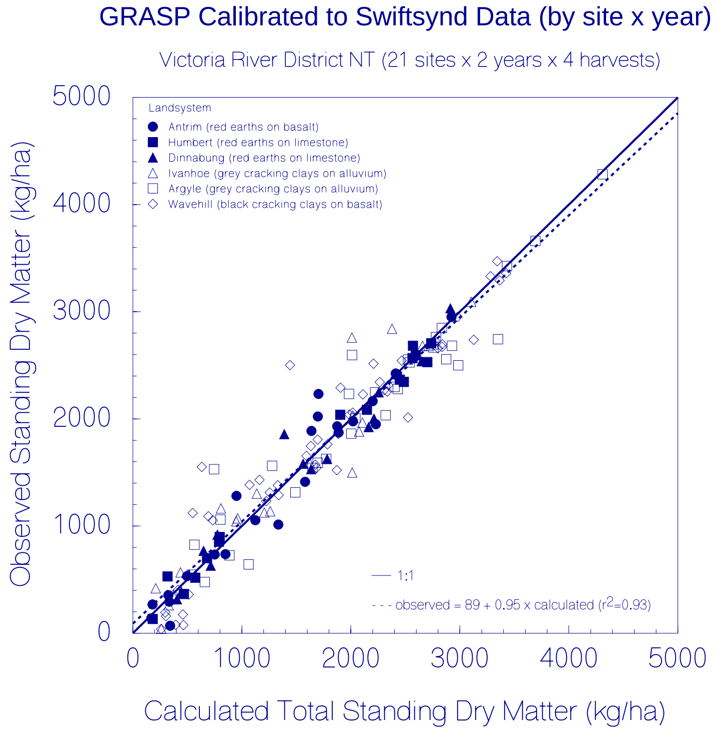


Figure A2. Relationship between observed and simulated pasture biomass for the SWIFTSYND sites following calibration of the GRASP model.

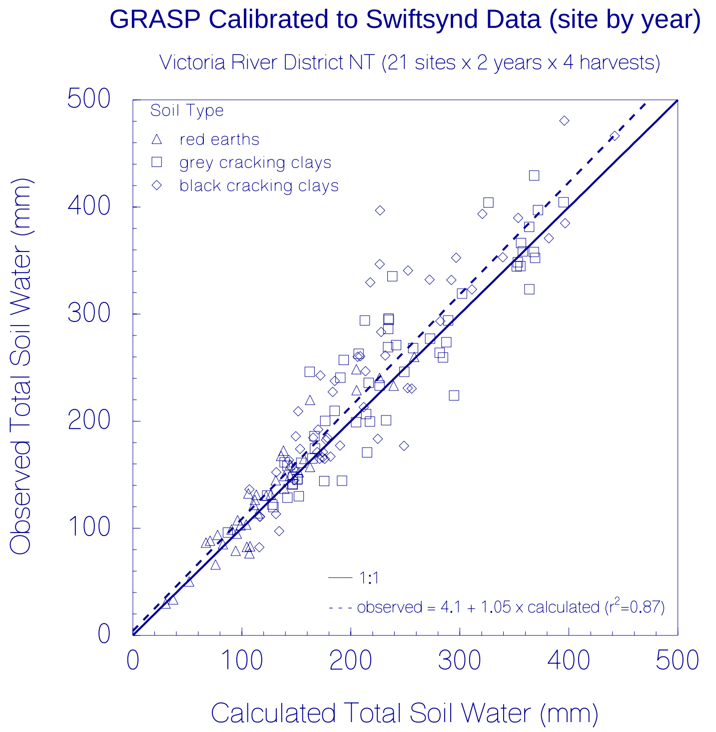


Figure A3. Relationship between observed and simulated soil moisture for the SWIFTSYND sites following calibration of the GRASP model.

Table A3. Average GRASP parameters for SWIFTSYND sites in VRD based on land systems and soil types, and average Queensland parameters derived by Day *et al.* (1997). Readers will find a full description of each of the parameters in Littleboy and McKeon (1997) or the help notes of the WinGRASP model (Timmers *et al.* 1999). (NB Table continued over page)

Parameter name	Parameter No.	Qld C4	VRD Average (21 Sites)	Antrim (basaltic red earths)	Humbert	Dinnabung	Ivanhoe	Argyle	Wavehill (black cracking clays)	Grey cracking clays	Calcareous red earths
AD	019	10	4	4	3	3	5	4	5	4	3
WP1	029	10	9	8	8	7	11	9	10	10	8
FC1	026	25	41	35	34	28	45	43	48	44	31
WPL2	030	40	41	39	26	40	47	40	43	43	33
FCL2	027	100	147	123	98	115	163	143	180	153	106
WPL3	031	50	54	40	3	15	77	66	68	71	9
FCL3	028	100	145	122	9	33	200	175	184	188	21
DEPTHL3	022	500	386	500	50	100	500	500	383	500	75
DEPTHTOT		100	89	100	55	60	100	100	88	100	58
PAWC1		15	32	27	26	21	34	33	38	33	23
PAWCL2		60	107	85	72	75	117	103	137	110	74
PAWCL3		50	91	82	6	18	123	109	117	116	12
TOTALPAWC		125	230	193	104	113	274	244	291	259	109
PAWC10cm		12.5	26	19	19	19	27	24	33	26	19
Runoff	270	1	0	1	1	1	0	0	0	0	1
Cracking	035	0	0	0	0	0	1	1	1	1	0
Nupt0	097	5	3.4	3.0	7.0	1.0	3.5	3.8	2.4	3.7	4.0
Nupt100mm	098	6	10.5	10.0	10.0	14.0	8.5	8.7	12.2	8.6	12.0
MaxNupt	099	20	22.9	22.5	18.0	21.0	25.0	21.3	24.7	23.2	19.5
MaxPercN	100	2.5	2.6	2.5	2.5	2.5	2.5	2.5	2.7	2.5	2.5
PercN0gr	101	.68	0.74	0.80	0.68	0.70	0.65	0.81	0.65	0.73	0.69
PercNmaxgr	102	.78	0.84	0.90	0.78	0.80	0.75	0.91	0.75	0.83	0.79
minpcNgrn	110	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
minpcNdd	111	0.4	0.58	0.85	0.45	0.60	0.40	0.57	0.48	0.48	0.53

Parameter name	Parameter No.	Qld C4	VRD Average (21 Sites)	Antrim (basaltic red earths)	Humbert	Dinnabung	Ivanhoe	Argyle	Wavehill (black cracking clays)	Grey cracking clays	Calcareous red earths
Yldcov50	045	1,000	1529	600	1725	1775	1525	1392	1745	1458	1750
Yldcov50	046	1,000	1529	600	1725	1775	1525	1392	1745	1458	1750
Yldcov50	271	1,000	1529	600	1725	1775	1525	1392	1745	1458	1750
Height1000	096	20	12.5	11.0	11.5	14.0	11.8	12.8	12.9	12.3	12.8
PGBA	005	1	2.6	7.2	2.8	1.7	4.5	1.8	2.7	3.2	2.3
RegPerBA	006	3.5	8.9	2.5	8.0	12.5	6.0	8.0	8.8	7.0	10.3
Regrowth		3.5	17.7	18.6	22.5	20.0	27.0	13.9	21.9	20.4	21.3
Transpiration Use Efficiency	007	13.5	10.9	8.5	11.5	11.5	9.0	11.2	10.8	10.1	11.5
SWIXat0grow	149	0.30	0.16	0.01	0.30	0.30	0.30	0.30	0.01	0.30	0.30
SWIXatMaxCov	009	0.30	0.96	0.15	1.00	1.00	1.00	1.00	1.00	1.00	1.00
DetLfWet	128	.004	0.0023	0.0008	0.0005	0.0008	0.0031	0.0025	0.0018	0.0028	0.0006
DetStWet	129	.004	0.0023	0.0008	0.0005	0.0008	0.0031	0.0025	0.0018	0.0028	0.0006
DetLfDry	130	.002	0.0023	0.0008	0.0005	0.0008	0.0031	0.0025	0.0018	0.0028	0.0006
DetStDry	131	.002	0.0023	0.0008	0.0005	0.0008	0.0031	0.0025	0.0018	0.0028	0.0006
TBA	291	0	0	0	0	0	0	0	0	0	0
WPL1tree	292	10	4.1	3.7	3.0	3.3	4.7	4.1	4.7	4.4	3.1
WPL2tree	293	40	40.8	38.7	25.5	40.0	46.7	40.0	43.3	43.3	32.8
WPL3tree	294	50	54.1	40.0	2.8	15.0	76.7	66.3	67.5	71.5	8.9
Max soil evap.	033	5	4	4	4	4	4	4	4	4	4
Evap. cracks	036	0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
I15 – constant	004	1.016	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
I15 - slope	005	0.465	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7

13.3.2 Validation of general model parameters

Tables A4-7 show observed biomass at the beginning of the dry season for the major soil types at five locations. In order to obtain a representative sample of biomass for a soil type, pasture biomass data were averaged over several SWIFTSYND data at a given location. Although each exclosure was selected as representative of a particular pasture condition state for a given soil type, each exclosure is nonetheless only a 'point' sample of the soil type. Hence biomass data for several exclosures were averaged in order to reduce 'within soil type' variability in the data set. To increase the representativeness of the biomass data for a soil type, only data from SWIFTSYND exclosures with typical species composition for a given soil type and location were considered (Table A1). The sites excluded from the analysis were also the same as those excluded in determining average plant parameters (listed previously).

Calculated biomass is shown for parameter sets based firstly on the average parameters for the VRD (Table A4) and secondly for model calculations based on parameters for four major soil types (Tables A5-7). In tables A6 and A7 the data is split into two even groups according to 'year type': 1) a 'drier year group (1993/94, 1995/96, Table A6); and 2) a 'wetter year' group (1994/95, Table A7). Splitting the data in this manner permitted an evaluation of how the model accounted for differences between year types.

The average parameter set for the VRD provided model calculations which were in close agreement with observed biomass except for basaltic red soils and, to a lesser extent, black soils at Rosewood Station (Table A4). When parameters were split according to the four major soil types, calculated biomass for the basaltic red soils was in closer agreement with the observed biomass (Table A5).

Table A4. Observed and calculated biomass at the beginning of the dry season. Calculations are based on average VRD parameters.

Soil type	Location	Observed biomass (kg DM/ha)	Calculated biomass (kg DM/ha)	Difference (kg DM/ha)
Red soils (basalt)	Mount Sanford	1964	2716	752
Red soils (limestone)	Kidman Springs	2626	2718	92
Black soils (basalt)	Mount Sanford	2622	2430	-192
	Rosewood	2423	2762	339
Grey soils (alluvium)	Kidman Springs	2921	2714	-207
	Victoria River Downs	2888	2960	72
	Auvergne	2553	2710	157
Average red soils		2295	2717	422
Average black soils		2523	2596	73
Average grey soils		2787	2795	7
Average all soils		2535	2703	168

Table A5. Observed and calculated biomass at the beginning of the dry season. Calculations are based on parameters for four major soil types.

Soil type	Location	Observed biomass (kg DM/ha)	Calculated biomass (kg DM/ha)	Difference (kg DM/ha)
Red soils (basalt)	Mount Sanford	1964	2114	150
Red soils (limestone)	Kidman Springs	2626	2592	-34
Black soils (basalt)	Mount Sanford	2622	2518	-104
	Rosewood	2423	3094	671
Grey soils (alluvium)	Kidman Springs	2921	2695	-226
	Victoria River Downs	2888	2674	-214
	Auvergne	2553	2634	81
Average red soils		2295	2353	58
Average black soils		2523	2806	284
Average grey soils		2787	2668	-120
Average all soils		2535	2609	74

Table A6. Observed and calculated biomass at the beginning of the dry season for drier years (1993/94,1995/96). Calculations are based on parameters for the four major soil types.

Soil type	Location	Observed biomass (kg DM/ha)	Calculated biomass (kg DM/ha)	Difference (kg DM/ha)
Red soils (basalt)	Mount Sanford	1964	2114	150
	Kidman Springs	2563	2366	-197
Black soils	Mount Sanford	2239	2346	107
	Rosewood	2008	3094	453
Grey soils	Kidman Springs	2651	2402	-249
	Victoria River Downs	2682	3050	368
	Auvergne	2781	3012	231
Average red soils		2264	2240	-24
Average black soils		2124	2404	280
Average grey soils		2773	2696	117
Average all soils		2364	2488	124

Table A7. Observed and calculated biomass at the beginning of the dry season for a wetter year (1994/95). Calculations are based on parameters for the four major soil types.

Soil type	Location	Observed biomass (kg DM/ha)	Calculated biomass (kg DM/ha)	Difference (kg DM/ha)
Red soils (basalt)	Mount Sanford	-	-	-
	Kidman Springs	2689	2820	131
Black soils	Mount Sanford	3004	2690	-314
	Rosewood	2837	3727	890
Grey soils	Kidman Springs	3191	2989	-202
	Victoria River Downs	3093	2297	-796
	Auvergne	2326	2256	-70
Average red soils		-	-	-
Average black soils		2921	3209	288
Average grey soils		2870	2514	-356
Average all soils		2827	2959	122

Apart from black soils on Rosewood Station, model calculations based on parameters for the four soil types were in close agreement with observed biomass (absolute error <300 kg DM/ha between observed and calculated biomass, Table A5). The absolute error between observed and calculated biomass was also low in dry years (<370 kg DM/ha, Table A6) but increased somewhat in wet years, particularly for the grey soils on Victoria River Downs (796 kg DM/ha, Table A7). The poorer performance of the model in wet years has been previously reported for Queensland (Day *et al*. 1997) and Zimbabwe (Day *et al.* 1999). In the GRASP model, production potential is governed by two parameters which describe: 1) potential nitrogen uptake; and 2) the degree to which plants can dilute nitrogen before growth stops. Both parameters tend to be site specific and can vary from one year to the next depending on nitrogen mineralisation (in the case of potential N uptake) and species composition (in the case of the percent nitrogen at which growth stops). Possible reasons for the poor fit for grey soils at Victoria River Downs in 1994/95 are not explored here but are addressed in M. Cobiac's thesis (in prep.). However, possible reasons for the over-prediction of biomass for black soils at Rosewood Station are considered below as is the rationale for splitting red soil parameters into two groups (basaltic and calcareous).

13.3.3 High biomass calculation for black soils at Rosewood Station

Pasture biomass for black soils at Rosewood station were over-predicted by the average black soil parameters. As discussed previously, potential site productivity is governed by two parameters: 1) maximum nitrogen uptake; and 2) percent nitrogen at which growth stops. Based on individual site x year parameters, the two black soil sites on Rosewood have a lower potential productivity (2573 kg DM/ha averaged across 2 sites and 2 years) compared to the potential productivity based on average black soil parameters (3792 kg DM/ha). This difference was mainly attributable to a difference in potential nitrogen uptake (16.4 kg/ha averaged across 2 sites and 2 years for Rosewood compared to 24.7 kg/ha for the average black soil parameters). The reason for the lower average N uptake for black soils on Rosewood was not clear. The highest observed N uptake for any year or site was 21 kg/ha (Site 18 in 1995). Even this value was lower than the average N uptake for black soils (24.7 kg/ha) as noted above. M. Cobiac and R. Dyer noted in a recent (August 2000) visit to these sites that pasture condition was markedly improved since the sites were initially sampled. Hence the years sampled may not have been indicative of the site potential and further field evaluation is required to establish this point.

13.3.4 Justification for splitting red soil parameters into two groups

Separate parameter sets for basaltic and calcareous red soils resulted in model calculations in close agreement with observed biomass for both soil types (average absolute error 150 kg DM/ha or less, Table A5). If red soil parameters were lumped into a single group, the 'average red soil parameters' resulted in a higher biomass calculation for limestone soils than observed (average absolute error 780 kg DM/ha). Hence separate parameters for basaltic and calcareous red soils would appear warranted. Inspection of Table A3, lends further support to this suggestion. A comparison of parameters listed in Table A3 for Antrim land system (basaltic red earth) with Humbert and Dinnabung land systems (both calcareous red earths), shows that most parameters were similar for the calcareous soils. However several key soil and plant parameters differ between calcareous red soil and basaltic red soil sites.

Soil available water range was higher for basaltic red soils (Antrim 193 mm) compared to calcareous red soils (Humbert and Dinnabung 104 mm and 113 mm respectively). The difference in soil available water range was mainly attributable to differences in available water range for layer 3 (Antrim 82 mm; Humbert and Dinnabung 6 mm and 18 mm respectively) which, in turn, was due to a difference in depth of this third soil layer (Antrim 50 cm; Humbert and Dinnabung 5 cm and 10 cm respectively). The basaltic red soils examined in this study were shallow in terms of depth to the C horizon (layer 3). However the C horizon in these soils was permeable and a time-series of observed soil moisture from the SWIFTSYND sites showed that water was extracted from this layer. In comparison the C horizon for calcareous red soils sampled in this study remained continually dry.

Differences in plant parameters between basaltic and calcareous red soils included, for example, percent nitrogen at which growth stops (Antrim 0.80%, Humbert and Dinnabung 0.68% and 0.70% respectively); yield at 50% cover (Antrim 600 kg DM/ha, Humbert and Dinnabung 1725 and 1775 kg DM/ha respectively); soil water index at zero growth (Antrim 0.01, Humbert and Dinnabung 0.30 in both cases); and soil water index at maximum cover (Antrim 0.15, Humbert and Dinnabung 1.00 in both cases). The differences in plant parameters were most likely attributable to a more general parameter difference between annual short grasses (on the basaltic red soils) and perennial grasses (on the calcareous red soils). This possibility could be further evaluated based on SWIFTSYND data from Mt Sanford, as burning of the Mt Sanford annual short grass sites in late 1994 resulted in a shift in species composition to perennials in the 1994/95 season. The change in model parameters and species composition for these sites is discussed further in M. Cobiac's thesis (in prep.).

13.4 Summary and conclusions

The GRASP model was successfully calibrated to 42 site x year combinations of pasture and soil measurements in the VRD. The calibrated site x year parameters provided a basis for deriving more general parameter sets for the Aussie GRASS spatial model. Model calculations based on a general parameter set for the entire VRD were in agreement with observed biomass at most locations with the exception of calcareous red soils and black soils at one location. An average parameter set for calcareous red soils provided a closer simulation of biomass on this soil type. Model calculations based on parameter sets for the four major soil types (calcareous red soils, basaltic red soils, basaltic black cracking clays and alluvial grey cracking clays) were in close agreement with observed pasture biomass for all but one soil type at one location (black soils at Rosewood Station). Model calculations based on parameters for the four major soil types also accounted for observed differences in productivity between drier and wetter years. However, the productivity difference between wet and dry years was not well simulated for grey alluvial soils at Victoria River Downs.

Based on findings presented here, average model parameters for the four major soil types (calcareous red soils, basaltic red soils, basaltic black cracking clays and alluvial grey cracking clays) are recommended for use within the Aussie GRASS model. Parameter values for these soil groups are listed in Table A3). Data used to validate the models were also used in the calibration process so further independent validation would be required to confirm the generality of the model parameters presented here.

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