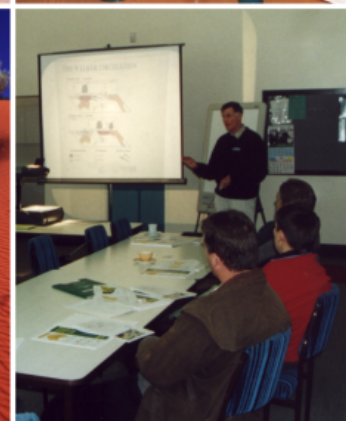
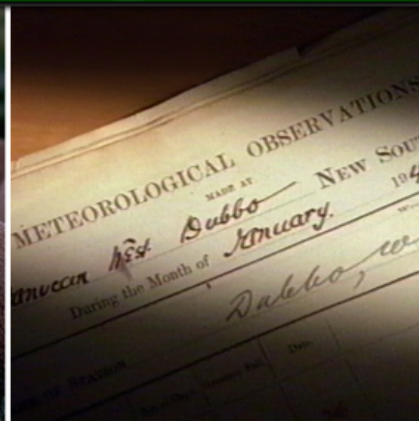


The Aussie GRASS

FINAL REPORT

April 2001



**Australian Grassland and Rangeland
Assessment by Spatial Simulation
(*Aussie GRASS*)**

QNR9

Final Report

For the

**Climate Variability
in Agriculture Program**

April 2001

**Wayne Hall, Dorine Bruget, John Carter, Greg McKeon,
Jyoteshna Yee Yet, Alan Peacock, Rob Hassett and Ken Brook**

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Department of Natural Resources and Mines, Queensland
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1. Project title

Australian Grassland and Rangeland Assessment by Spatial Simulation
(short title: Aussie GRASS)

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3. Collaborators

The Aussie GRASS project was a multi-agency collaborative project and involved the following agencies and personnel:

- *Queensland Department of Natural Resources and Mines (NR&M)* – Dorine Bruget, John Carter, Greg McKeon, Alan Peacock, Ken Brook, Jyo Yee Yet, Lisa Collett, Neil Flood, Ken Day, Rob Hassett, Stephen Jeffrey, Alan Beswick, Keith Moodie, Peter Timmers and Michael Gutteridge.
- *Queensland Department of Primary Industries (QDPI)* – Col Paull, Neil Cliffe, Damien O’Sullivan, Ross Ballin, Paul Walmsley and Ron Wheeler.
- *Northern Territory Department of Primary Industry and Fisheries (NTDPI&F)* – Rodd Dyer, Linda Cafe, Scott McIntyre, Michael Cobiack, Trudi Oxley, Katrina McMahon and Jeff Werth.
- *Agriculture Western Australia (Ag WA)* - Greg Beeston, Ian Watson, Julie Wyland, Matt Bolam, Andrew Craig, Simon Osborne and Tom Denman.
- *Primary Industries and Resources, South Australia (PIRSA)* - Rodger Tynan and John Maconochie.
- *Department of Environment, Heritage and Aboriginal Affairs, South Australia (DEHAA)* – Russell Flavel.
- *Department of Land and Water Conservation, New South Wales (DLWC)* - Daryl Green, Rob Richards, Alan McGufficke and Koshy Varghese.
- *New South Wales Agriculture* - Ron Hacker, Judy Bean, Steve Clipperton, Graeme Tupper, John Crichton, Doug Alcock and Harpal Mavi.

4. Project objectives

The Aussie GRASS proposal listed the following overall objectives for the project:

- 1) Further technical development and eventual operationalisation of ‘Aussie GRASS’, a national grassland and rangeland assessment model (whose prototype was developed in LWRRDC QPI20) that can explore and calculate:
 - pasture and shrubland growth using the best mix of State and CSIRO models;
 - climatic and drought analyses;
 - the historical context of various biophysical values, including pasture biomass;
 - the question of herbivore carrying capacity, and land sustainability; and
 - the quantitative risks of land degradation in the context of local State environments, animal numbers and seasonal climatic forecasts.
- 2) Facilitating a nationally co-ordinated effort of spatial grazing modelling, that:
 - is developed in partnership with collaborators, stakeholders and clients,
 - builds national teamwork, national co-operation, sharing of model technology and validation methods;
 - creates research synergies;
 - transfers technology to local State units; and
 - yet allows collaborators to self-actualise with local modelling efforts and research emphasis.
- 3) Development of a nationally integrated extension program that:
 - targets at and markets to land management clients at a district scale;
 - delivers climatic risk and grazing management products to landholders, local drought and catchment committees, land care groups, land managers, and executive government;
 - is delivered by local agencies in each State, yet sharing common national extension lessons and technical distribution systems; and
 - is developed by participative group processes that produce a process of iterative development and feedback.
- 4) Development, calibration and validation of the best pasture models for different ecoclimatic zones such as:
 - the winter perennial/shrubland zone across the south of the continent (Western Australia (WA), South Australia (SA), western New South Wales (NSW)), and
 - the high rainfall temperate pasture systems of eastern NSW.
- 5) Further calibration and validation of the GRASP pasture model in the Northern Territory (NT) and Kimberley, as well as integrating the extent of savanna burning in the NT and WA. Burning is increasingly becoming monitored by complementary remote sensing programs (e.g. the NT Bushfire Council).
- 6) Facilitate the development of a national distribution system that provides at a continental scale, both a standardised archive of historical NOAA imagery; and a

standardised regular feed of newly acquired imagery, that have been processed, navigated, radiometrically corrected and mosaiced to an agreed national standard.

7) Explore how to interface:

- new seasonal climate forecasting systems such as produced by the Bureau of Meteorology Research Centre's (BMRC's) new sea surface temperature (SST) principal component analysis (this system unlike the Southern Oscillation Index (SOI) has considerable skill in southern Australia); and
- also potentially within the project's lifetime, forecasts from general circulation models (GCMs) of the atmosphere produced by the US Scripps Institution of Oceanography, USA, and the CSIRO Division of Atmospheric Research (DAR).

8) Explore ways to develop synergies with other relevant research projects and also how to supplement the funding base for such a large national project. For example:

- the next LWRRDC general funding round will be approached for further research funding on rainfall interpolation and rainfall mapping by GMS-5 satellite imagery;
- GRDC will be approached to partially fund the interfacing of the new Bureau of Meteorology forecasting system based on sea surface temperatures; and
- in the final year of this proposal, the States and NT will make their own assessments about the long-term nature of the project and start to increasingly self-fund the operation, including core maintenance overheads.

The project was divided into a number of sub-projects (see Section 5), each of which had their own specific objectives. The objectives for the key sub-projects are detailed in Section 6.

5. Summary of methods and modifications

The Aussie GRASS project was divided into eight sub-projects on the basis of their focus and/or geography:

- 1) Core development and co-ordination – led by Wayne Hall, NR&M;
- 2) Extension – led by Col Paull, QDPI;
- 3) Southern Pastures – led by Greg Beeston, Ag WA;
- 4) High Rainfall Zone Temperate Pastures – led by Graeme Tupper, NSW Agriculture;
- 5) NT & Kimberley Rangeland – led by Rodd Dyer, NTDPI&F;
- 6) NOAA data – led by Greg Beeston, Ag WA;
- 7) State and NT funded activities to enhance point and spatial data sets; and
- 8) Development of all States and NT access to NR&M computing systems.

Given the number of sub-projects, their diversity and complexity, it is not possible to 'summarise' the methods used in each sub-project. Instead, detailed reports have been prepared for the following sub-projects:

- Extension – Paull *et al.* (2001);

- Southern Pastures – Richards *et al.* (2001);
- High Rainfall Zone Temperate Pastures – Tupper *et al.* (2001); and
- NT & Kimberley Rangeland – Dyer *et al.* (2001).

The key results from all eight sub-projects are outlined in the following section.

6. Results, their interpretation and practical significance

The results from the four main sub-projects (Extension, Southern Pastures, High Rainfall, Kimberley & NT) are presented below against the specific objectives of the sub-project. The results of the minor sub-projects (Core, NOAA data, Spatial data, Computer access) are presented against ‘summary’ objectives for each.

6.1. Extension sub-project

6.1.1. Objective 1: Identify and/or assist in the development of a range of user-friendly ‘Aussie GRASS’ decision-support products of potential value to managers of properties, local drought committees, catchment managers, and government land and policy administrators in the pastoral industries of Australia

A range of 28 products (mainly maps) was identified/developed for each State and the NT, including some Australia-wide maps. An additional five products cover only Queensland (Qld). These products can be grouped as follows:

- recent rainfall;
- current pasture production/condition;
- drought situation (Qld only);
- forecast rainfall/pasture condition; and
- integration of products.

The main current business applications of the information products, by managers in pastoral industries, are in the areas of:

- policy decisions and policy support (products have been used regularly by drought policy officers in Qld);
- buying/selling/agisting stock, e.g. many graziers in Qld sold stock, or abandoned plans to purchase stock, in March 1997 as an El Niño event developed;
- pasture management, e.g. excluding stock from a paddock to build up fuel for a fire to control woody weeds;
- planting pastures/crops, e.g. planting sown pastures only when the seasonal climate forecast is favourable for a good establishment;
- pest and disease control, e.g. in southern Qld good summer rainfall followed by a mild winter may result in significant additional costs to control cattle ticks and buffalo fly, and necessitate an early start to follow-on control measures in the following spring; and
- feed supplies, e.g. purchasing feed and animal supplements in anticipation of a poor season, when they are readily available at a reasonable price.

6.1.2. Objective 2: Develop the 'Aussie GRASS' products by participative processes in a series of iterative consultations and facilitated workshops

A wide range of workshops/learning activities was conducted involving extension staff, primary producers, agribusiness, and government personnel to create awareness of the project and obtain feedback on prototype products. A total of 25 Aussie GRASS workshops was conducted around Australia (Table 1).

The Aussie GRASS project and resulting products were promoted through a variety of client group activities in Qld and the NT, and to a lesser extent in the other States. Feedback on the prototype products and their perceived value was collated and discussed with staff concerned with research and development. Where possible, products were modified in response to needs expressed by clients.

Table 1. Aussie GRASS workshop times, locations and participant numbers.

Month and Year	Location	Number of Participants	Progressive Totals	
			Number of Workshops	Number of Participants
Oct 1997	Emerald, Qld	7	1	7
Oct 1998	Orange, NSW	6	2	13
Oct 1998	Cobar, NSW	20	3	33
Nov 1998	Katherine, NT	18	4	51
Nov 1998	Alice Springs, NT	17	5	68
Dec 1998	Perth, WA	12	6	80
Dec 1998	Perth, WA (vide/teleconference)	12	7	92
Dec 1998	Adelaide, SA	17	8	109
Dec 1998	Broken Hill, NSW	3	9	112
May 1999	Brisbane, Qld	13	10	125
June 1999	Roma, Qld	15	11	140
June 1999	Toowoomba, Qld	19	12	159
Nov 1999	Rockhampton, Qld	5	13	164
Nov 1999	Emerald, Qld	6	14	170
Nov 1999	Gayndah, Qld	17	15	187
Feb 2000	Carnarvon, WA	19	16	206
Feb 2000	Perth, WA	19	17	225
Feb 2000	Kununurra, WA	8	18	233
Mar 2000	Balranald, NSW	17	19	250
Mar 2000	Dareton, NSW	5	20	255
Mar 2000	Adelaide, SA	16	21	271
May 2000	Brewarrina, NSW	10	22	281
Sep 2000	Dalby, Qld	7	23	288
Oct 2000	Munduberra, Qld	8	24	296
Nov 2000	Dalby, Qld	8	25	304

6.1.3. Objective 3: Make products available to a wide range of clients

Sample products, and guidelines for their interpretation, were initially produced and distributed to a wide range of clients including extension officers, policy officers, agribusiness and pastoralists. This was followed by regular distribution of selected products to key clients; for example, in some Qld regions selected products were distributed monthly to members of Local Drought Committees. Similarly, large numbers

of information kits and sample products were distributed widely at major extension events, media events and through other activities undertaken as part of the communications strategy.

Up-to-date products were made available on self-serve information systems operated by the Queensland Centre for Climate Applications: 'The Long Paddock' and Aussie GRASS (password protected) web sites; SOI Fax Hotlines and FarmFax; SOI Phone Hotline; and on FarmLink (e-mail system). In addition, products were distributed by direct mailing in all States and the NT.

6.1.4. Objective 4: Facilitate the training of national extension staff in the use of the 'Aussie GRASS' products, in conjunction with seasonal climate outlook information, in making management decisions

The 'Assessing Pastoral Situation (Aussie GRASS) Workshop' was developed to train managers and extension staff involved in pastoral industries throughout the rangelands. The content of the one-day workshop was customised according to the needs of participants in a particular State or Territory. The intention was to help produce better-informed decision-making in pastoral areas, involving a sustainable balance between production and sound land management. The aims of the workshop were to:

- create an awareness of the Aussie GRASS project, and how its range of products were produced;
- familiarise participants with the individual products and how to interpret them;
- give participants information on how to access Aussie GRASS decision-support products and related information;
- help participants to improve their skills in using the information products to make management decisions in pastoral industries more timely, profitable and sustainable; and
- provide feedback on individual products to aid the improvement of current products and the development of new ones.

6.1.5. Objective 5: Obtain client feedback: the value and presentation format of individual products; and other related climate/pasture growth products that would be useful (on an industry by region basis)

Considerable feedback on the various products was obtained from clients and extension staff at group activities, through interaction with individual clients, and from surveys. This feedback was used in the modification of prototype products and delivery systems, and the development of new products.

Feedback from most participants in the workshops was very positive, and many of the products were regarded as valuable for helping with management decisions in pastoral areas. However, there were some reservations regarding the accuracy of some products, and the applicability of seasonal climate forecasting in some regions of Australia

Some of the most important feedback collected, and acted upon where feasible and appropriate, was:

- The scales used in some mapping products were sometimes inappropriate, due to wide seasonal variations in values, resulting in most of a map being in one or two colour categories. While some changes have been made, the problem has not been fully overcome due to technical difficulties and varying client needs.
- Clients wanted to have both a State map and an enlargement of their region/district, but there were some technical difficulties in addressing this need. There is also the risk that some clients will misuse the scale of a particular mapping product. However, ERDAS LAN files were made available on the web site, and they can be readily customised to satisfy the needs of individual clients.
- Changes required in the presentation format of some products (e.g. sea-surface temperature mapping product; adding major towns and roads), and the need for other related types of information (e.g. a graph of the average SOI over the previous 30 days).

Many of these comments have been acted upon while some requests still need to be addressed.

6.1.6. Objective 6: Promote the integrated use of 'Aussie GRASS' products with: Property Management Planning (PMP) workshops/activities; and information systems/tools designed to help graziers manage for climatic variability, e.g. the DroughtPlan products.

Use of Aussie GRASS products was promoted at workshops, other group activities and major extension events, particularly in Qld and the NT. Product use was frequently linked with other decision-support information/tools for the purpose of making profitable business decisions, particularly Australian Rainman and DroughtPlan products. Furthermore, in Queensland, three combined Aussie GRASS-Australian Rainman workshops were conducted. These associated products were also promoted at other extension activities.

6.1.7. Objective 7: Carry out pre- and post-project benchmarking of the knowledge, attitudes, skills and aspirations of clients to formally describe the changes that have occurred during the project

The pre-project survey questionnaire was developed to produce a 'snapshot' of graziers' knowledge, attitude, skills and aspirations in the assessment of seasonal conditions. Over 360 questionnaires were distributed in the various States/Territory (Table 2).

State/Territory	Distributed	Returned
Queensland	100	65
New South Wales	86	54
South Australia	90	49
Western Australia	50+	26
Northern Territory	60	23
Total	364	217

Table 2. A summary of how the survey was conducted, results and conclusions is given below.

Individual reports were produced for each State/Territory plus a national summary – these are listed in Section 9. Some of the main findings from the survey were:

- 81% percent said that judgements of future climatic conditions were ‘very important’ or ‘moderately important’ in their decision making.
- 75% of participants did not use long-term climatic records to assist in decision making.
- 44% said that probability-based information was ‘moderately useful’ to ‘very useful’ in the management of their business.
- 37% of participants were currently using seasonal climate forecasts in decision making.
- 42% of respondents said ‘big-picture’ information was ‘moderately important’ to ‘very important’ in their planning.
- 28% of respondents had no problem using ‘big-picture’ information. However, some had problems with interpreting and using it (22%), and the information was not detailed enough for others (15%). The comments under ‘Other problems’ indicated some reservations about product accuracy and forecasting ability.
- ‘It is better management practice to simply respond to changing seasonal conditions, rather than try to anticipate and reduce seasonal climatic risks’ - 48% either ‘agree’ or ‘strongly agree’ with this statement.
- ‘I accept that seasonal climate forecasts are better expressed in terms of probabilities (e.g. ‘60% chance that the next three months will be drier than average’) than like a traditional weather forecast’ - 65% ‘agree’ or ‘strongly agree’ with this statement.

The survey results were used within this sub-project to modify the Extension program and Communications Plan.

While the original intention was to conduct both a pre- and post-project survey, it was found that the initial survey consumed far more extension resources, particularly time, than anticipated and it was expected that in many pastoral districts the extension program would not have been operating long enough to produce substantial changes. Consequently, the following recommendation was submitted to the Steering Committee, and endorsed, in April 1999: that the post-project survey not be conducted in the life of the project so that extension resources can be focused on workshops and other client group activities. It is recommended that a follow-up survey be conducted after 3-5 years of extension of Aussie GRASS products.

6.2. Southern Pastures sub-project

6.2.1. Objective 1: Undertake a rigorous systems review of IMAGES, ARIDGRO, SEESAW, and GRASP for use in southern Australia.

A systems review of the relevant pasture production models was undertaken using the following framework:

- 1) obtain model documentation and available literature;
- 2) examine and compare model biological processes;
- 3) obtain model source code (except SEESAW);
- 4) identify and collate suitable data sets to use with the models; and

5) assess model performance.

The models were also to be assessed on the basis of their input data requirements, ease of calibration and potential for incorporation within the existing spatial modelling framework.

While the reviews of IMAGES (Hacker *et al.* 1991) and ARIDGROW (Hobbs *et al.* 1994) were undertaken by the Aussie GRASS project team, a contract was established between CSIRO and DLWC in order to achieve the above processes for the SEESAW pasture production model. A document detailing the operation and function of the SEESAW model was produced by CSIRO (Hodgkinson and Marsden 1998) and used in the review of the model. Similar documentation was obtained for IMAGES and ARIDGROW.

Reports reviewing the SEESAW, IMAGES and ARIDGROW pasture production models can be found as part of the sub-project final report or stand alone reports (Watson 1999). The model reviews included *Objectives 2 and 3*. Rigorous review of the models indicated that each was devised for specific purposes and thus used varying biological processes and had differing scales of applicability and input/output parameters.

6.2.2. Objective 2: Develop a consensus view of what model, models, or model combination should be used

The models were assessed on the basis of their performance (i.e. ability to account for variability in observed data), input data requirements, ease of calibration, and potential for incorporation within the existing spatial modelling framework.

A comparison of the CSIRO ephemeral pasture production model ARIDGROW and GRASP found that calibration of GRASP allowed it to account for a higher amount of variation in total standing dry matter (TSDM) for four of the five sites for which data were available in central Australia. A full report on the simulations and comparison of the ARIDGROW and GRASP models is presented in the Southern Pastures Sub-project Final Report (Richards *et al.* 2001).

Watson (1999) in his detailed examination of the simulation results of IMAGES for the Boolathana grazing trial identified three factors that would prevent the inclusion of shrub biomass estimates in the Aussie GRASS spatial framework: 1) no model is currently available that can simulate browse biomass well; 2) for most vegetation types the separation of browse into 'eaten' and 'uneaten' will be very difficult; and 2) shrub biomass will always depend on the condition of the system. Thus Watson (1999) recommended that: 1) it was naïve for the Aussie GRASS project to assume that it could model absolute biomass of shrub-dominated systems, especially given vegetation mapping resolution would not allow edible shrub density to be mapped with any accuracy; and 2) that resources were best concentrated on parameterising the existing Aussie GRASS model as a best estimate of herbage biomass production in shrub dominated systems. The GRASP model has previously been shown by McKeon *et al.* (1996) to simulate 62 – 72% of the variation in observed non-shrub biomass for the four Boolathana sites examined in their work. The full findings of the work by Watson (1999) and additional work using data from Roshier, NSW, are contained in the Southern Pastures Sub-project Final Report (Richards *et al.* 2001).

Details of the evaluation of the SEESAW and GRASP models are contained in Richards *et al.* (2001). Existing GRASP parameter sets were tested but independent validation was only achieved on a few sites in western NSW for which data were available. GRASP was then calibrated to the first two TSDM observations in each time series using the single parameter 'potential regrowth rate'. Other site parameters (available soil water, tree density, species composition) were estimated from inputs used in SEESAW. The use of calibrated site-specific regrowth parameters or an average across the eight sites explained a reasonable proportion of variation ($r^2 > 0.69$) for six sites. Comparison with SEESAW simulations, without further calibration, indicated that GRASP and SEESAW were in reasonable agreement ($r^2 > 0.70$) for seven sites and very close agreement ($r^2 > 0.88$) for four sites. Whilst GRASP does not attempt to represent the variation in behaviour of plant guilds over time that SEESAW does, nevertheless, for sites of known composition, GRASP can represent a similar proportion of variation in TSDM as SEESAW. Results from the SEESAW simulations (detailed in Marsden and Hodgkinson 1998) also show that whilst total biomass may have been simulated well, there was often poor agreement between each of the observed and simulated guilds, i.e. errors in simulation of annual forbs, perennial forbs, C₃ grasses and C₄ grasses cancelled each other out so as to produce a good simulation of TSDM.

Given the above finding it was recommended that there is currently little potential benefit to be gained from the inclusion of the ARIDGROW, IMAGES or SEESAW models within the Aussie GRASS modelling framework, and that the GRASP model is the preferred option in terms of both simulation performance and input data requirements.

6.2.3. Objective 3: Collate the necessary pasture and shrubland data necessary to parameterise the models

A thorough literature search of suitable data sets was undertaken in order to achieve this objective. Of the 15 data sets collected by NSW Agriculture and DLWC, only five (Bean and Clipperton 1999) were suitable for model parameterisation and validation as per *Objective 4*. CSIRO supplied an additional six data sets (Marsden 1998) that were used for parameterisation.

Unfortunately, difficulties were experienced in identifying historic data sets of suitable quality for calibration and validation of the models, and hence comparison of model outputs. The suitability of data was limited by incompleteness, suspect data, inappropriate data, and differences in temporal and spatial applicability. The numerous difficulties encountered in the use of these historic data sets emphasises the need for future data from grazing trials etc. to be collected with a view to their being used in a modelling framework. The SWIFTSYND technique (Day and Philp 1997) provides one approach whereby quality data suitable for pasture modelling can be obtained quickly and efficiently.

In addition to the above data used in the review of the models, spatial data were also collected to use as inputs to the national model. This included improved data on kangaroo and goat numbers, soil layer characteristics and vegetation community composition. In conjunction with the Bureau of Meteorology (BoM), the NSW project team arranged for eighteen producers to join the Bureau's NSW volunteer telegraphic rainfall reporting network. An unsuccessful attempt was also made to establish a system

to obtain timely stock figures on an annual basis for Rural Lands Protection Boards in western NSW.

6.2.4. Objective 4: Validate the model against historic time series data sets, annual ground monitoring and vehicle transects

As a result of the model evaluations undertaken as part of *Objective 2*, the decision was made to continue to use GRASP across the southern pastures within the Aussie GRASS modelling framework. The next step was to spatially calibrate and validate the Aussie GRASS model. Three sources of additional data were used: 1) 'spider mapping' data; 2) Rangeland Assessment Program (RAP) data; and 3) NOAA Pathfinder imagery. (N.B. all historical time series data collated as part of *Objective 3* were used in the model evaluation process)

The majority of the spatial model calibration and validation was performed using data sets collected from extensive field surveys, or spider mapping, in each of the relevant States. Field surveys took place between mid 1998 and early 2000. Validation parameters collected included visual estimates of pasture biomass (almost 60,000), tree/shrub cover and chenopod density. Data were collected using a computerised data acquisition system consisting of a laptop computer, global positioning system and on screen real time map navigation using satellite images. While each State's method varied slightly, they were based on the technique developed by Hassett *et al.* (2001) as part of the Development of a National Drought Alert Strategic Information System project.

Some difficulties were experienced in collecting data in some vegetation communities such as the heavily infested 'woody shrub' communities of western NSW. Attempts were made to establish a relationship between tree/shrub basal area and foliage projected cover. No reliable relationship was found, although a very strong relationship existed between foliage projected cover and canopy cover. Data collected during extensive field surveys are the most critical for model calibration/validation but it is resource demanding. There is scope for further refinement of methods used and further validation using spider mapping techniques.

The RAP data set has been collected by DLWC since October 1989 and includes measures of pasture biomass. Data were available for 334 locations with each site having between 2-11 observations.

6.2.5. Objective 5: Interface the best model or models to the "Aussie GRASS" spatial framework.

Given the conclusions of work undertaken as part of *Objective 2*, it was not necessary to interface any of the reviewed models into the national Aussie GRASS modelling framework within the scope of this project.

6.2.6. Objective 6: Based on the best southern Australian models, develop regional specific information products aimed at the pastoral industry, catchment management committees and State government agencies in:- decision support, vegetation management, grazing management, drought declaration, and land degradation prevention.

Information products derived and used included a range of absolute and relative data and spatial maps. These included monthly growth and growth relative to historic records for 3, 6, 12 and 24-month periods, and rainfall relative to historic records for the same periods. Other information products included spatial maps of grassfire risk and seasonal outlooks for rainfall and pasture growth. These products were promoted through the Extension sub-project (see Paull *et al.* 2001 for more details). Many of these information products were well accepted and generated considerable interest from a range of government and non-government users such as Rural Fire Services, Rural Land Protection Boards (RLPBs), conservation agencies, Landcare groups and individual landholders.

6.3. High Rainfall Zone Temperate Pastures sub-project

6.3.1. Objective 1: Run GrassGro at specified locations in all relevant shires in NSW, using up-to-date weather information and information on local soil types and pasture species. The simulations will be based on an indicator herd or flock – say Merino wethers or Angus steers – stocked at a typical rate for the district.

GrassGro was run routinely at 65 localities, typical of high rainfall NSW, using published soil information where available and local weather data provided by the Silo project. RLPB districts were preferred to shires as they are of more even size. Simulations were based on a flock of Merino wethers stocked at a conservative rate for the district based on the long-term carrying capacity obtained by modelling and the local weather record. A program of regular simulations and product generation is now in place.

6.3.2. Objective 2: Run the simulations forward in time to obtain a probability distribution of the likely state of the production system in 3 weeks, 3 months and 6 months time using the SOI analogues or other appropriate forecast system that develops.

Under specified deteriorating conditions at particular localities, GrassGro was run forward for a three-month period to obtain the likely duration and severity of a feed shortage or other event. Analogue years and other appropriate forecasting systems were evaluated as experimental forecasting tools. However, the choice of forecasting system remains subjective and as a result of simulation experiments undertaken as part of this sub-project, it was decided to use the variance of the local weather record to obtain a temporal probability using percentiles. This information was then interpreted using official forecasts from BoM. A probability distribution map of pasture growth, based on RLPB Districts and derived from the simulations was produced regularly for validation by regional officers.

The development of the GrassGro-equivalent temperate parameter sets for the Aussie GRASS model (see Section 6.3.7) means that three-month forecasts of pasture growth for the eastern half of NSW are produced each month as part of the operational spatial model runs. The Aussie GRASS model uses the DPI SOI phase system to select analogue years.

6.3.3. Objective 3: Check the output against PROGRAZE demonstration data, MRC SGS program data, and other grazing trials.

Due to the nature of the GrassGro model, validation requires long periods of pasture data combined with stock information. There is also a need for detailed soil analysis, including bulk density and moisture holding characteristics. It was originally hoped that NSW Agriculture's Pasture Animal Assessment Program (PAAP) would provide useful validation data. While pasture type and available data were suitable at some PAAP sites, no information was available regarding soil parameters. Validation has been attempted with data from the Beef CRC project at Glen Innes but experimental design (including long periods without pasture measurements) precluded successful simulation of this complex grazing system.

In development of the GrassGro pasture growth model, many grazing experiments were reviewed by the CSIRO Plant Industry group for potential use in validation of the specific pasture parameter sets. Validation runs have been developed for several sites across southern Australia including several in NSW. The validation process by CSIRO is ongoing and all new iterations of the program are validated against standard data sets to ensure model stability in commercial releases. For this reason it was decided to accept the validation efforts of CSIRO as sufficient evidence of the suitability of the GrassGro model for use in the temperate high rainfall environments and to spend greater effort in development of a method for its use in the Aussie GRASS project.

6.3.4. Objective 4: Collate species data from researchers and the literature

It was recognised early in the development of the Aussie GRASS project that the existing set of parameterised species for GrassGro was restrictive and limited the geographical extent over which GrassGro might be used, particularly in hot/dry seasonal environments. Under the Aussie GRASS project, the task of developing a wider set of parameterised species for GrassGro was contracted to CSIRO with the emphasis placed on developing ecotypes for certain native grasses.

6.3.5. Objective 5: Develop parameters for additional species from collated data

See Objective 4.

6.3.6. Objective 6: Map GrassGro output in New South Wales Agriculture's Geographic Information Systems (GIS)

The output from GrassGro simulations was mapped on an RLPB District basis using GIS software. An example is shown in Figure 1.

NSW Agriculture regional staff were involved in Aussie GRASS via a co-operative pilot project which was initiated in December 1999. District staff reviewed products and contributed to the accuracy and timeliness of GrassGro output. Their feedback was invaluable in developing the Relative Livestock Performance graphs based on Metabolisable Energy Intakes, which were used to illustrate seasonal pasture conditions (Figure 2).

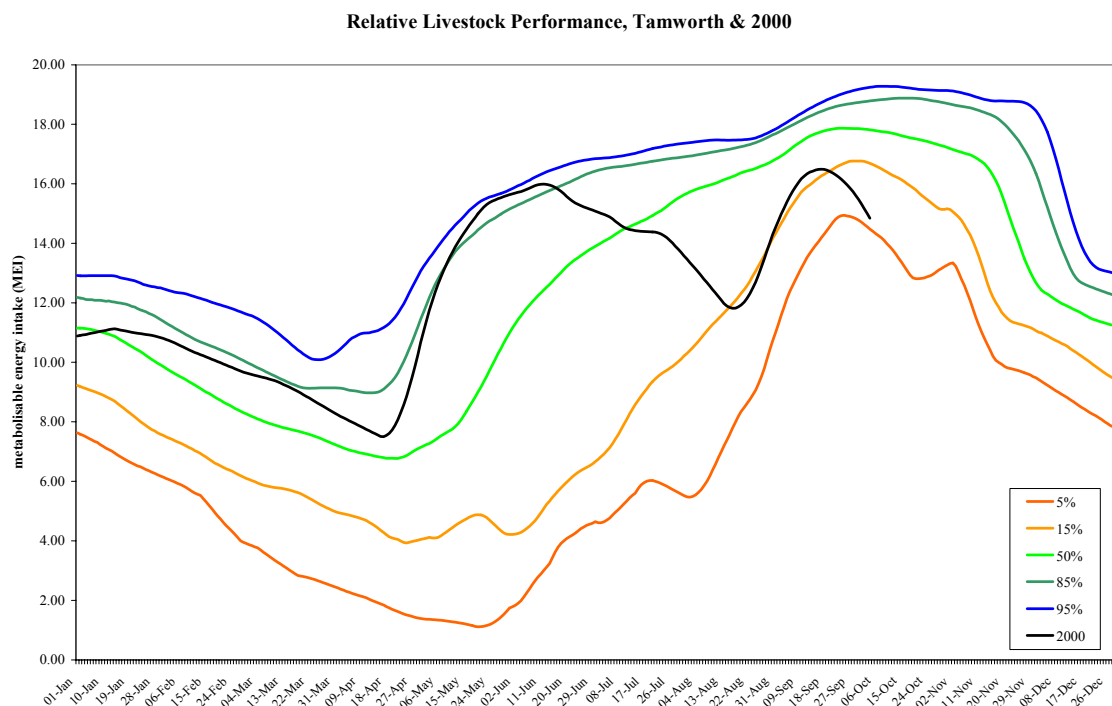


Figure 2. Relative Livestock Performance graph for Tamworth as at the end of September 2000.

6.4. NT & Kimberley Rangeland sub-project

6.4.1. Objective 1: Complete calibration and validation of current SWIFTSYND / GRASP sites in the VRD and Katherine region of the NT

The calibration of 21 GRASP sites in the Katherine region has been completed in conjunction with the MLA Sustainable Pasture Management project (NTA 022). These sites represent important pasture communities 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. Generic parameter sets have been developed for these major pasture/soil systems and have been used to help derive parameter values in the Aussie GRASS spatial model.

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

Extensive spider mapping has been undertaken throughout the NT and Kimberleys 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 (87,000 NT; 25,000 Kimberley). Observations of pasture community type, fire scars and feral animals were also recorded. Detailed calibration data were collected from 567 sites (268 NT; 299 Kimberley).

6.4.3. Objective 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

NT GRASP sites were used to develop general parameter sets for several important land systems within the NT and Kimberley. These parameter sets have then been used to help derive parameter values in the Aussie GRASS spatial model.

Over 110,000 observation points collected as part of Objective 2 were also used to calibrate and validate these and other land systems covered as part of the spider mapping exercise. The resultant parameter sets are now being used operationally in the spatial model to provide products for the NT and the Kimberley.

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

The Aussie GRASS project, through both the NT and WA participants, is actively involved in a major NHT Fire Management Project aimed at ground truthing NOAA derived active fire hot spot and fire scar maps. This work is currently underway.

6.4.5. Objective 5: Provide updated spatial data for modelling inputs regarding stock numbers, levels of utilisation, tree canopy cover and on property rainfall

In the last couple of years the annual Australian Bureau of Statistics (ABS) agricultural census has been downgraded to a survey with only a reduced number of properties sampled. In the NT however the government has provided additional funds to ABS to maintain a full census. As a result the accuracy and resolution of ABS data of the NT data provided to 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 expected potential producer cooperation and available personnel and resources. The NT is currently involved in a National Land and Water Resources Audit funded project that 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 improve the vegetation layer.

During property visits managers/owners were requested, where not already doing so, to consider joining BoM's 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 to the BoM in Darwin for consideration.

6.4.6. Objective 6: Assist in the development of modelling products relevant to requirements in northern Australia and based on data collected in the Northern Territory

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.

6.4.7. Objective 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.

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, WA and the NT. 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 many property visits.

6.5. Core development and co-ordination sub-project

This sub-project, as the name suggests, was not a stand alone project, but rather worked to ensure that the multi-agency, geographically diverse project teams were able to achieve their tasks and link them within the overall project umbrella. This Final Report represents the final task for the Core team. Other major achievements of the Core team have been:

- development of the password protected Aussie GRASS website which has provided collaborators and clients with access to the full range of Aussie GRASS products;
- ensuring the Aussie GRASS model was run immediately upon receipt of monthly climate data from BoM, and that the output was processed and products placed on the website;
- sourcing of additional funds for Aussie GRASS activities from the CRC for Tropical Savannas and the National Land and Water Resources Audit;
- having the Aussie GRASS project awarded the 1998 Queensland IT&T John Hesketh Award for Excellence (government section);
- liaising with other groups to develop new products, e.g. the range of 'fire products';
- undertaking the calibration and validation of the spatial model using field data supplied by the collaborators; and
- facilitating the next phase of the Aussie GRASS project (see Section 8).

6.5.1. Calibration and validation of the Aussie GRASS 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 which vary.

The current operational model is parameterised using: 1) data collected by field observation; and 2) greenness data (Normalised Difference Vegetation Index - NDVI) from the NOAA satellite. Field observations may include detailed soil and pasture data

collected using SWIFTSYND technique, and more coarse data collected using the spider mapping technique. Spider mapping exercises undertaken in the project collected 171,342 useable biomass observations, with 86,755 collected in the Northern Territory alone. In addition, 2,795 biomass observations for NSW were available from the Rangeland Assessment Program (RAP).

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/RAP 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 30% of data were withheld from this process and used as a check on model performance. Observations falling within a given pixel (25 km²) 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 or more pixels, or in other words, approximately ¼ of a Statistical Local Area as mapped by the Australian Bureau of Statistics.

6.5.1.1. Calibration results

Full calibration results are detailed in each of the sub-project Final Reports. Summary calibration and validation results using the field data are shown in Figure 3, and calibration results using NDVI in Figure 4.

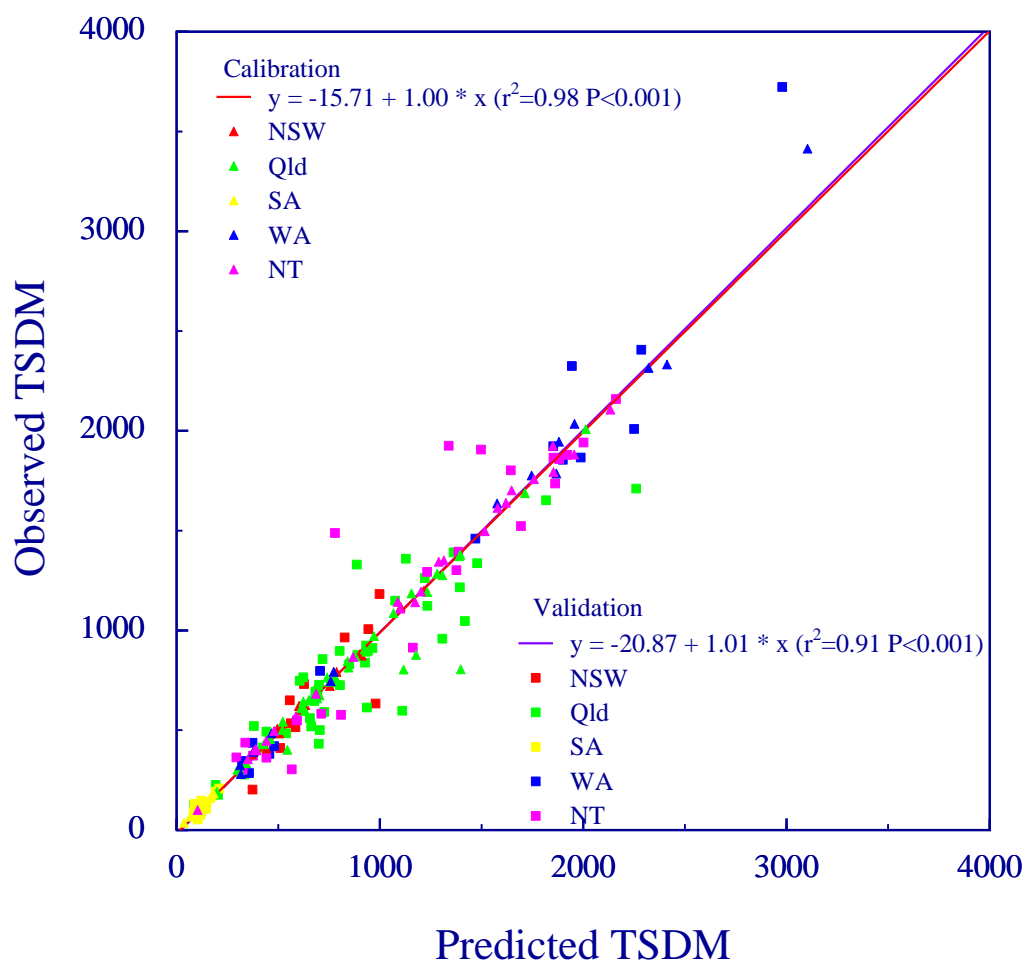


Figure 3. Calibration and validation results using available spider mapping/RAP field data. Each of the data points represents the mean of all observations, on a pixel basis, made within a specific Aussie GRASS vegetation community.

There were four vegetation communities for which a strong agreement between observed and predicted mean TSDM did not occur: buck Spinifex and mudflats (WA); heath (Qld); northern blady grass (Qld); and southern Queensland blue grass (Qld). Factors that contributed to the relatively poor results for these communities included the effects of poor tree mapping and small numbers of pixels sampled within the vegetation community. As only one-third of the available data was held over for the model validation process, it was not surprising that this latter problem also appeared to have a major affect on the validation results. The vegetation communities with relatively poorer validation results based on mean TSDM values were: hard spinifex on sand dunes (Qld - 47 pixels); heath (Qld - 6 pixels); southern Queensland blue grass (Qld - 5 pixels); buck spinifex and mudflats (WA – 32 pixels); teatree-samphire low open shrubland (NT – 4 pixels); and gidgee over barley Mitchell grass (NT – 6 pixels).

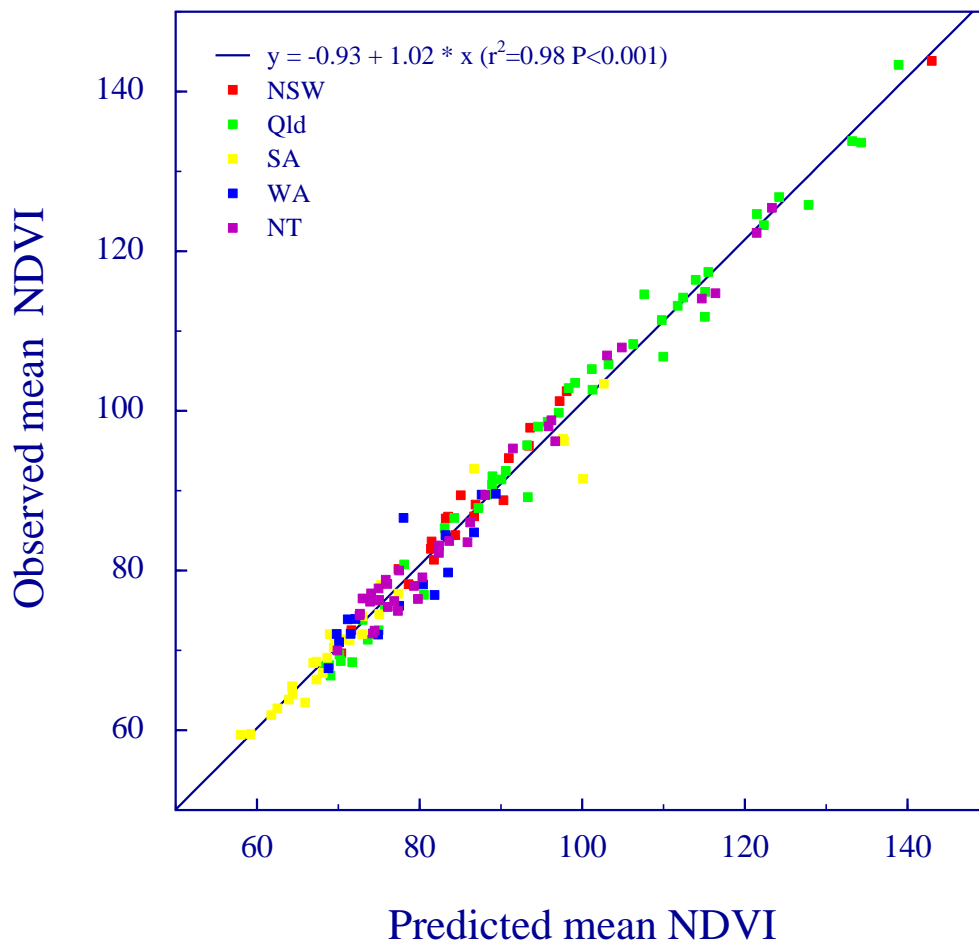


Figure 4. Calibration results using NOAA NDVI data. Each of the data points represents the mean of all satellite observations, on a pixel basis, made within a specific Aussie GRASS vegetation community.

6.5.1.2. 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 NT proved very useful in those and related areas.
- Errors in the tree density map where basal area was over or under estimated by one or two units (m^2/ha). These errors are most noticeable in coastal and sub-coastal 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.
- Large and poorly mapped plant communities (notable in Western Australia, eastern New South Wales)
- Availability of fire scars maps for all States/Territories.

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.

6.6. NOAA data

The main objectives of this sub-project were to:

- facilitate the development of an Australian standard for the processing of NOAA data; and
- promote the use of NOAA-derived products to other groups, especially those relating to fire risk and fire monitoring.

Whilst the Aussie GRASS agencies operating in northern Australia have all been involved in NOAA-related fire work, especially through the CRC for Tropical Savannas, the main thrust of this sub-project, facilitation of the development of an Australian standard for the processing of NOAA data, was overtaken by developments within CSIRO, thus making this sub-project largely redundant. The Earth Observation Centre within CSIRO has the responsibility for co-ordination of all CSIRO groups involved in the processing of NOAA data and is funding the development of the Common AVHRR Processing System (CAPS). CAPS aims to incorporate the best algorithms for dealing with both instrument and physical problems encountered during NOAA processing. The CAPS program to-date has focused on developing standard software that first addresses the instrument problems. In addition, a CAPS developers' group is being established which will provide collaborators with free access to the CAPS source code and an environment in which knowledge and algorithms can be freely contributed to the program. However, it should be noted that many of the physical problems, e.g. atmospheric distortion, encountered during the processing of NOAA data will not be easily resolved.

The changes to the tasks within this sub-project were endorsed by the Steering Committee at the meeting on the 1st May 1998. The funds within this sub-project were subsequently distributed to the collaborating agencies to fund additional spider mapping as it was considered by the project team to be the activity with the highest priority.

6.7. State and NT funded activities to enhance point and spatial point and spatial data systems

The objective of this sub-project was to improve, where possible, all major inputs to the Aussie GRASS model. A major success in this area has been the interaction of NR&M, NSW Ag and DLWC with BoM to identify new volunteer observers for BoM's rainfall reporting network.

NR&M identified 28 existing 'postal reporting' stations that it wished to have upgraded to 'telegraphic' in order to improve the timeliness of reporting in certain priority areas. In addition, NR&M, in conjunction with QDPI, identified 19 new strategically located volunteers for BoM's reporting network. Similarly, NSW Ag and DLWC identified 18 new strategically located volunteers in the Western Division of NSW.

The other major improvements in Aussie GRASS inputs have been achieved through the sourcing of additional funding from the National Land and Water Resources Audit. This has involved two projects:

- 1) Change in land tenure/land use – has provided a better historical picture of where grazing was carried out on a decadal time step (Gutteridge *et al.* 2000).
- 2) Intensity of land use – involves the digitising of historical data from ABS, and other sources, relating to grazing pressure.

Both projects have either been recently completed or are nearing completion and it is expected that the results will be incorporated into Aussie GRASS in the coming months.

NR&M have also recently regenerated the full library (1890-current) of rainfall rasters using an improved rainfall normalisation procedure within the kriging process.

6.8. Development of all States and NT access to NR&M computing systems

The specific objectives of this sub-project can be classified into three broad activity areas:

- 1) *Enable collaborators direct access to NR&M computing systems.* This objective has not been achieved largely due to problems with ensuring the security of data, software and hardware during off-site accessing of systems. NR&M is still struggling with these issues despite having considered various options. However, collaborators and other clients have been provided with direct access to the range of Aussie GRASS products via the password protected Aussie GRASS website. Data is available in the form of gif, postscript and ERDAS LAN file formats.
- 2) *Ensure local officers have the necessary software and hardware to successfully use and extend the Aussie GRASS products.* This issue was largely beyond the control of the project team because of resource considerations. However, the project team has strived to ensure that the data on the web sites is available in a variety of formats that provide for the range of skills, software and applications of most users.
- 3) *Provide for the maintenance of the Aussie GRASS computing infrastructure.* Apart from a contribution early in the project from NSW Agriculture, the Aussie GRASS infrastructure has been maintained solely by NR&M. However, the next

phase of Aussie GRASS will involve a contribution by all continuing collaborators to the personnel and computing resources required to maintain Aussie GRASS (see Section 8 for more details).

7. Communication and adoption

The Aussie GRASS project proposal recognised the importance of communication activities to the success of the overall project and hence had a dedicated Extension sub-project dealing with communication and adoption issues. An overview of the activities of the Extension sub-project is provided in Section 6.1 while a separate detailed report was provided by Paull *et al.* (2001).

8. Aussie GRASS - the future

It is the belief of all the project members that the Aussie GRASS project has been worthwhile from both a personal and professional perspective. To this end, the agency representatives at the 'Aussie GRASS operationalisation workshop' in April 2000 supported the proposal for an ongoing Aussie GRASS program to be funded directly by the States and Territory. Since then, various briefings and proposals have been made to the departments involved. At the time of writing, NSW Agriculture, DLWC and Ag WA have committed themselves to Aussie GRASS for a two-year period. A large resource monitoring proposal, including Aussie GRASS, is currently before the NT cabinet with a decision on funding expected in the coming months. Unfortunately, the key Aussie GRASS personnel in SA (within DEHAA) have recently been transferred to another department and hence the lobbying for support and funds has had to recommence.

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10. Sources of additional information

The main text sources of additional information on the Aussie GRASS project are the overview paper by Carter *et al.* (2000), and the detailed sub-project reports (Dyer *et al.* 2001, Paull *et al.* 2001, Richards *et al.* 2001, Tupper *et al.* 2001). Alternatively, additional information on the project, including future plans may be obtained from Wayne Hall (07 3896 9612, wayne.hall@dnr.qld.gov.au).

11. Additional references

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