On farm

# Pasture Theme

*Sustainable Grazing Systems*

**Project number SGS.412**
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Feedbase and Pastures

## CONTENTS

# 1. HIGHLIGHTS

- Development of the experimental protocols as a common set of data for cross-Site analysis.

- SGS database that provided a single repository for data at each Site, easy access to the data collected and queries to extract data in a form required by the Theme.

- Exchange of information and ideas between Theme members and those involved in other parts of SGS National Experiment.

- Involvement of farmers in a participatory R&D approach that added value to the research.

- Cross-Site analysis that resulted in the principle that "Sustainable and productive pastures based on sown perennial grasses in the high rainfall zone (HRZ) of southern Australia will need to be grazed at high stocking rates (15-23 DSE/ha) in combination with rotational grazing or resting, and with adequate soil P (soil Olsen P > 20 mg/kg). Additional gains in production and sustainability can be obtained by ensuring an adequate legume component (10 to 20%), including a $C_4$ perennial grass and ameliorating soil acidity (pH ($CaCl_2$) of these acid soils to be >4.7). Pastures based on native perennial grasses will require lower soil P and more conservative stocking rates, depending on species".

- Use of the model as part of the cross-Site analysis, which confirmed that increases in herbage accumulation due to rotational grazing were likely to be minor and that deep-rooted $C_3$ and $C_4$ perennial grasses could potentially increase herbage accumulation.

- Preparation of the Pasture Theme paper for the special edition of AJEA, and the focus it provided for the analysis.

- Harvest Year, which provided the Theme with support (post-doc) and allowed time to complete the analysis and write up the results.

- New research ideas such as the possible benefits of deep rooted $C_3$ and $C_4$ perennial grasses for improved herbage accumulation and water-use.

# 2. BACKGROUND

Pastures, both improved and unimproved, make up approximately 83% of the agricultural zone of southern Australia. The most common pasture type in NSW is unimproved native pasture. Subterranean clover-based pastures are most common in Victoria and WA, medic-based pastures in SA, while perennial grass-based pastures are common in Tasmania. These pastures utilise water, sunlight, carbon dioxide and minerals to provide the bulk of the energy and nutrients required by grazing animals to produce meat in southern Australia.

Unfortunately, many of these pastures are also unproductive and/or unable to use sufficient water to prevent land degradation in the form of salinisation, soil erosion, nutrient contamination and soil acidification. In the high rainfall zone (> 600 mm) of southern Australia the Sustainable Grazing Systems Program (SGS) has been addressing these issues by undertaking research at a number of Sites across the southern HRZ, collectively called the 'National Experiment' (NE). This research is focussed on perennial grass based pastures that have the potential to enable productive and sustainable grazing of these lands.

The Pasture Theme was formed within the NE to develop the experimental protocols and undertake cross-Site analysis for the pasture data. To focus its effort the Theme addressed the following questions.

## 2.1 Theme questions

For the SGS experimental pasture types within the edaphic and climatic regions to which they are suited, determine:

1. What is the effect of farm management (eg. fertiliser use, grazing management) on pasture production and stability?

2. What is the impact of climatic and edaphic factors on pasture productivity and stability?

3. Which combinations of pasture and management in different edaphic and climatic zones provide productive and stable grazing systems?

Pasture stability is defined as the persistence (within acceptable limits) of a given botanical composition through time.

# 3. OVERVIEW OF PROGRESS

## 3.1 SGS (to June 2001)

By the end of June 2001 the Theme had completed the following;

1. Development of the experimental protocol relating to pasture measurements.

2. Implementation of the Theme queries into the SGS Database, notably the processing of BOTANAL data.

3. Input into the development of the SGS Pasture Model.

4. Preliminary analysis of the 1998, 1999 and 2000 data sets for (a) relationships between rainfall, photosynthetic active radiation (PAR) and annual herbage production and (b) factors influencing pasture stability.

The preliminary analysis found no clear relationship between rainfall, PAR and annual herbage production, but did suggest that the efficient use of every mm of rainfall (taken as the upper limit of the scatter of points on the graph) could result in 18 kg DM/ha. Improved soil fertility consistently increased herbage production, and sown pastures produced more herbage than native. Rotational grazing rarely increased herbage accumulation. Grazing management and soil fertility mostly drove changes in botanical composition. Perennial grasses were more persistent under rotational grazing.

## 3.2 Harvest Year

Much of the progress in the harvest year focussed on more extensive cross-Site analysis, use of the SGS Pasture Model to explore the Theme data, and publishing the Theme findings in a special edition of the Australian Journal of Experimental Agriculture. This effort was supported by 50% of a Post-doctoral position at the University of Melbourne (Brendan Cullen).

By the end of the Harvest Year (30 June 2002) the Theme had completed;

1. A special pastures edition of Prograzier magazine.

2. An extensive cross-Site analysis exploring climate, pasture, management, soil and water factors that were responsible for driving annual herbage accumulation and pasture stability.

3. SGS Pasture Model simulations that explored the impact of grazing management and plant species on annual herbage accumulation over a 30 year period.

4. A draft of the Pasture Theme paper.

5. Updated Tips and Tools.

The findings of the above analyses (SGS and Harvest Year) are summarised in the findings section of this report and covered in detail in the attached draft of the Pasture Theme paper as at 31st October 2002.

# 4. PROGRESS TOWARDS TOOLS, RULES OF THUMB, GUIDELINES FOR PRODUCERS

The cross-Site analysis resulted in guidelines for producers; however caution has to be exercised as different pasture types and experimental treatments confounded the analysis. The guidelines however are likely to be extrapolatable to most of the HRZ, because the analysis was undertaken over a large geographical area and is supported by historical studies.

In addition to the Theme analysis a number of tools or guidelines relevant to the Pasture Theme were developed by individual Site teams.

This information is available to be included in the SGS Technical Manual, Tips and Tools and the SGS Diagnostic Tool.

## 4.1 Guidelines that emerged from the cross-site analysis

Sustainable and productive pastures based on sown perennial grasses in the HRZ of southern Australia will need to be grazed at high stocking rates (15-23 DSE/ha) in combination with rotational grazing or resting and with adequate soil P (soil Olsen P > 20 mg/kg). Additional gains in production and sustainability could be obtained by ensuring an adequate legume component (10 to 20%), including a $C_4$ perennial grass and ameliorating soil acidity (pH ($CaCl_2$) of these acid soils to be >4.7). Pastures based on native perennial grasses will require lower soil P and more conservative stocking rates, depending on species.

## 4.2 Site- or region-specific guidelines

- In conjunction with the NSW North West Slopes Regional SGS Producer Group, a Pasture Health Kit was produced for producers to use when assessing the health of their paddocks. This kit uses a simple seven-point checklist and provides a scoring pad, coloured photographs and background information. Also guidelines for the grazing management of native pastures on the North-West Slopes of NSW were compiled into a 4-page brochure. Over 5,000 kits and grazing management guidelines have been distributed.

- Information on phalaris management in a summer rainfall environment, on control of wiregrass and on kikuyu pasture management have been incorporated into the Tips & Tools series.

## 4.3 Findings, hunches and unanswered questions

### *4.3.1 Findings*

**Cross-site analysis**

Briefly, total annual rainfall was not a useful predictor of herbage accumulation across the range of environments covered by the NE, however a water use efficiency value of 18 kg DM/ha.mm was a limit rarely exceeded at any Site suggesting that this value could be a useful indicator of potential annual herbage accumulation based on rainfall when conditions are ideal (Fig. 1). An estimate of the number of months with soil stored water, determined by simple water balance of rainfall, potential evapotranspiration and soil water storage capacity, was a useful predictor of herbage accumulation across Sites, accounting for 30% of the variation (Fig. 2). Other factors that increased herbage accumulation were soil P, proportion of introduced species in the sward, stocking rate and interactions between factors including legume content. Thus the 18 kg DM/ha.mm empirical limit was attained when circumstances allowed the annual rainfall to be maximally effective for plant growth. The attached Theme paper (Sanford *et al.* 2003) provides a full account of the factors that determined annual herbage accumulation across the NE.

The management factors that consistently affected perennial grasses percent and basal cover across the NE were grazing management, stocking rate and soil pH. At high stocking rate a grazing management strategy that involves a rest from grazing is necessary to maintain tufted perennial grasses in the sward. The appropriate rest strategy depends on the pasture species and the environment, for example at Vasey a time-based rotation (2 weeks on, 6 weeks off) enhanced persistence of phalaris pastures, while at Carcoar summer deferment (around the time of reproductive development) was an effective strategy. Across all Sites higher soil pH (ie. more neutral) was associated with greater perennial grass content. Further details of these analyses are available in the attached paper (Sanford *et al.* 2003).

## Herbage accumulation techniques comparison

The cross-Site analysis led to questions about different methodologies for estimating annual herbage accumulation, specifically the reliability of using a BOTANAL-plus-estimated animal intake procedure (used at the Wagga Wagga and Yass Sites) as compared to exclusion cages (used at all other Sites). A small techniques comparison study was carried out to address this issue using data from the Carcoar (1999-2000), Vasey (1998-2000) and Albany (1999-2000) NE Sites, because these Sites and years had the most comprehensive pasture and animal production data sets.

*Methods.* Exclusion cages were used at each Site, but the techniques were slightly different. Briefly, to estimate herbage mass under exclusion cages a paired quadrat technique at 6-week intervals used at Carcoar, at Vasey a falling plate meter was used at 3-6 week intervals, and at Albany visual ranking was used every 3-4 weeks (further details of these methods are described in the attached Theme paper Sanford *et al.* 2003).

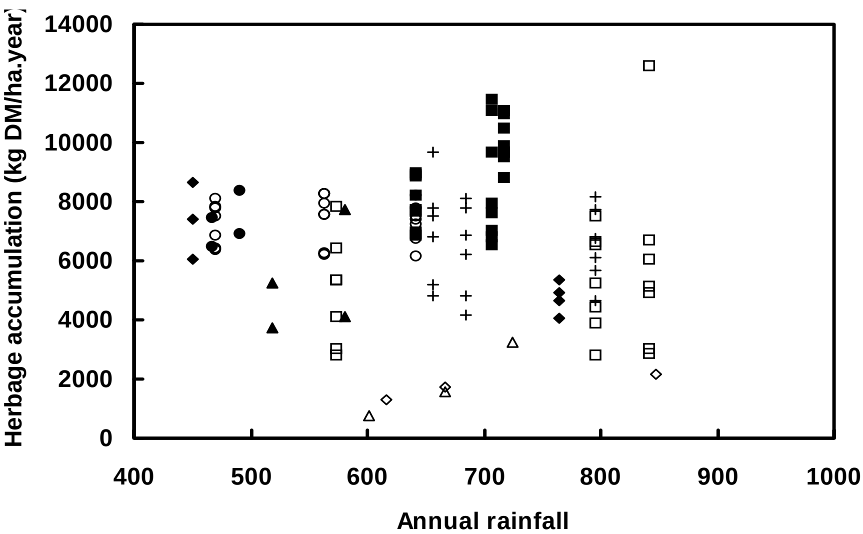


**Figure 1.** Relationship between annual rainfall (mm) a- herbage accumulation (kg DM/ha.year) for NE Sites at Manilla (◇), Barraba (△), Carcoar (□), Wagga Wagga (▲), Yass (+), Vasey (○), Esperance (◆), Albany (■) Kendenup (●), from 1997 to 2001.

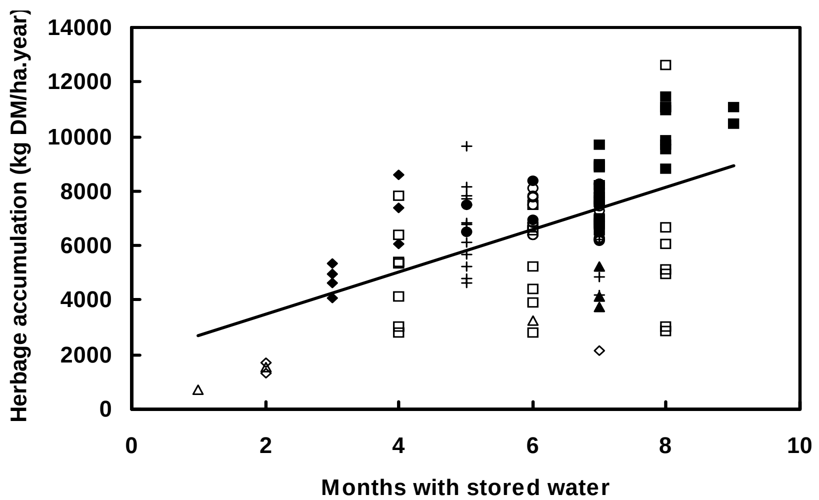

**Figure 2.** Relationship between months with stored water (as described by Fleck 1971) a-herbage accumulation (kg DM/ha.year) for NE Sites at Manilla (◇), Barraba (△), Carcoar (□), Wagga Wagga (▲), Yass (+), Vasey (○), Esperance (◆), Albany (■) Kendenup (●), from 1997 to 2001. The line depicts best-fit, $R^2 = 0.30$.

The BOTANAL-intake method estimated herbage accumulation by summing the change in green herbage mass and predicted animal intake for each calendar year. The change in green herbage mass was calculated at regular intervals during each year using BOTANAL measurements, that were carried out 3-4 weeks during the growing season at the Vasey and Albany Sites, and at 6-weekly intervals all year round at Carcoar.

Animal energy intake (MJ ME/sheep.day) was estimated using the principles of GRAZFEED, with the metabolisable energy (ME) content (MJ/kg DM) of the animals' diet being 10% higher than the measured pasture ME at each Site (see Fig 1 of Animal Production Theme final report). Where animals were supplementary fed (Vasey only) the ME content of the supplementary feed was used instead of pasture. The GRAZFEED equations were used to calculate the animals ME requirement based on liveweight, growth rate, pregnancy status, pasture ME, percent legume etc., then pasture intake (kg DM/sheep.day) was calculated as:

Pasture Intake (kg DM/sheep.day) = ME required (MJ ME/sheep.day) / ME of diet (MJ ME/kg DM)

These calculations were performed on individual animal measurements. The mean pasture intake per animal was calculated for each plot, then stocking rate (sheep/ha) was used to calculate pasture intake on a per hectare basis. Herbage accumulation over each period between BOTANAL measurements was then calculated as the change in green herbage availability plus estimated animal intake, and was zeroed if negative, then summed for the calendar year.

*Results.* A comparison of the annual herbage accumulation estimates using the cage and BOTANAL-intake method for each treatment is presented in Table 1. Agreement between the methods was closest at Vasey in 2000. A trendline fitted across data from all Sites and treatments showed that the relationship between the two techniques (Figure 3) had the equation:

BOTANAL-intake method = 0.45 x Exclusion cage method + 2872 ($R^2 = 0.49$)

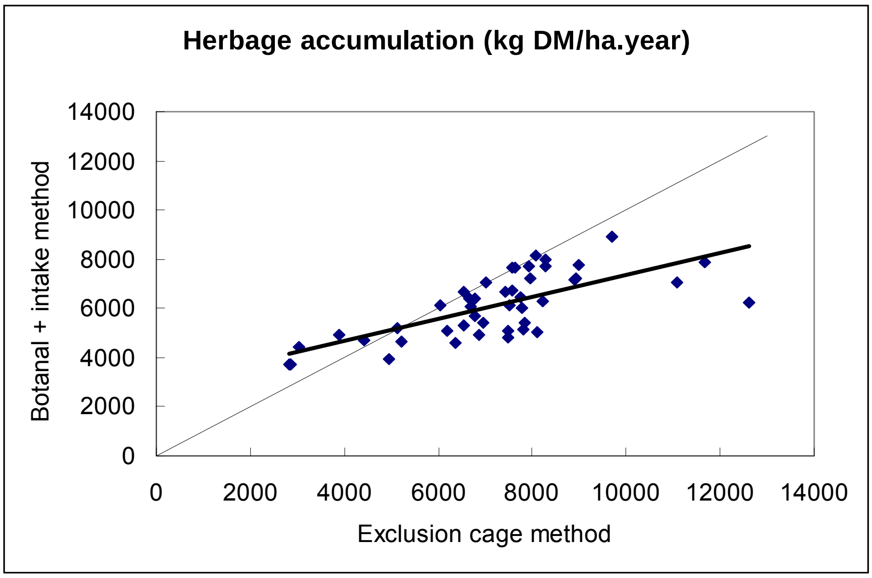


**Figure 3**. Relationship between the exclusion cage and BOTANAL- plus -intake methods for estimating annual herbage accumulation (kg DM/ha). The heavy line shows the fitted trendline (y = 0.45*x + 2872, $R^2$ = 0.49) and the light line indicates the 1:1 relationship.

*Discussion*. Agreement between herbage accumulation estimated by the exclusion cage method and BOTANAL-intake method was quite good. However, for amounts above 6,000 kg DM/ha.year the BOTANAL-intake method generally estimates less herbage accumulation than the exclusion cage method. While the exclusion cage method is most widely accepted it is not possible to confidently state it is the most accurate as its limitations are quite well know. It is however possible to speculate about the differences between the two methods. The exclusion cage method may over estimate herbage accumulation under grazing due to greater leaf area index within the cage compared to the grazed sward outside resulting in superior carbon assimilation under certain conditions. Equally the BOTANAL-intake method may under-estimate herbage accumulation because it only accounts for herbage loss due to ingestion by livestock not by other means such as trampling and bitting. In addition the method is reliant on an accurate assessment of the digestibility of forage consumed by the livestock, for example an increase of 10 units in digestibility can result in an increase in intake of 0.25 kg DM/sheep.day.

This preliminary analysis demonstrates that the BOTANAL-intake method of estimating annual herbage accumulation has promise and therefore warrants further investigation as an alternative method to the commonly used exclusion cage method.

**Additional findings**

Both set stocking and rotational grazing have strengths for particular pasture or animal production objectives. The most efficient grazing system will usually involve a combination of both at different stages of the annual cycle. The question should not be "is one grazing method better than the other?", because this is too simplistic. Rather, the questions should be "What am I trying to achieve? Does rotational grazing have a place in my system, and if so what level of intensity should I use, and when should I use some form of rotational grazing and when should I use set stocking?" A combination of different grazing methods is necessary to achieve sustainable, productive pasture systems The 'active' management system as currently practised discourages legumes. Retention of perennial grasses and legumes in the pastures will require some form of reciprocating management that perhaps encourages legumes in one year and encourages perennials in another (*eg.* summer rest for perennials, spring grazing for legumes).

**Table 1:** Comparison of exclusion cage and BOTANAL plus intake methods for estimating herbage accumulation (kg DM/ha.year), at the Carcoar, Vasey and Albany SGS NE Sites

| Site | Treatment | Year | Exclusion cage (kg DM/ha) | BOTANAL + Intake (kg DM/ha) | Difference (%) |
|---|---|---|---|---|---|
| Carcoar | Control/continuous | 1999 | 3890 | 4950 | +27 |
| | | 2000 | 3040 | 4410 | +45 |
| | Control/flexible | 1999 | 2820 | 3700 | +31 |
| | | 2000 | 2850 | 4230 | +48 |
| | Fertilised/continuous | 1999 | 6660 | 6380 | -4 |
| | | 2000 | 6050 | 6150 | +2 |
| | Fertilised/flexible | 1999 | 4410 | 4710 | +7 |
| | | 2000 | 4940 | 3940 | -20 |
| | Sown/continuous | 1999 | 6540 | 5290 | -19 |
| | | 2000 | 6690 | 6090 | -9 |
| | Sown/flexible | 1999 | 5230 | 4670 | -11 |
| | | 2000 | 5120 | 5220 | +2 |
| | Chicory | 1999 | 7500 | 5100 | -32 |
| | | 2000 | 12600 | 6220 | -51 |
| Vasey | Set stock, low P | 1998 | 6190 | 5070 | -18 |
| | | 1999 | 6380 | 4600 | -28 |
| | | 2000 | 7580 | 7300 | -4 |
| | Set stock, high P | 1998 | 6780 | 5670 | -16 |
| | | 1999 | 7500 | 4830 | -36 |
| | | 2000 | 8280 | 7710 | -7 |
| | Rotate 4 paddock | 1998 | 7420 | 6680 | -10 |
| | | 1999 | 8120 | 5030 | -38 |
| | | 2000 | 8290 | 8000 | -3 |
| | Rotate 8 paddock | 1998 | 7520 | 6130 | -18 |
| | | 1999 | 7800 | 5120 | -34 |
| | | 2000 | 7920 | 7700 | -3 |
| | Rotate 8 paddock + N | 1998 | 7780 | 5990 | -23 |
| | | 1999 | 7840 | 5400 | -31 |
| | | 2000 | 7570 | 7650 | +1 |
| Albany | Annual control | 1999 | 9690 | 8890 | -8 |
| | | 2000 | 8930 | 7230 | -19 |
| | Annual 20% trees E | 1999 | 7530 | 7650 | +2 |
| | | 2000 | 8890 | 7180 | -19 |
| | Annual 20% trees S | 1999 | 6790 | 6390 | -6 |
| | | 2000 | 6850 | 4910 | -28 |
| | Annual 20% trees W | 1999 | 7970 | 7190 | -10 |
| | | 2000 | 7750 | 6470 | -17 |
| | Annual 36% trees E | 1999 | 7030 | 7070 | +1 |
| | | 2000 | 8230 | 6290 | -24 |
| | Annual 36% trees W | 1999 | 6560 | 6660 | -2 |
| | | 2000 | 6960 | 5420 | -22 |
| | Kikuyu control | 1999 | 11660 | 7880 | -32 |
| | | 2000 | 8090 | 8160 | +1 |
| | Kikuyu 20% trees W | 1999 | 11080 | 7070 | -36 |
| | | 2000 | 8980 | 7790 | -13 |

- Rotational grazing practices can be adopted with no penalty in stocking rate or reduction in production. Continuous grazing leads to low levels of litter, low accumulation of dry material (standing haystack), low ground cover and high losses of water by runoff.

- For native pastures, rotational grazing strategies designed to accumulate litter, or allow plants to flower and set seed and seedlings to establish, need to incorporate rest periods of about 12 weeks (90 days).

- For increased Sirosa phalaris persistence in a summer rainfall environment pastures need to be lightly grazed or de-stocked for 6 weeks from stem elongation in spring and again for 6 weeks following good rains in autumn, to allow for tiller development. Continuous grazing will lead to low persistence.

- Simple assessments of ground cover, litter, herbage mass, percent green, proportion of legume and proportion of perennial grasses can be used by producers to give in-the-paddock assessments of the productivity and sustainability of a pasture.

- The stoloniferous perennial grass kikuyu is both persistent and productive under intensive continuous grazing.

- On phalaris/sub clover pastures, rotational grazing increases phalaris content and decreases sub clover content compared to set stocking.

- Rotational grazing increases phalaris content compared to set stocking mainly by increasing individual tiller/plant size. Rotational grazing also leads to better phalaris survival, and more phalaris clumps per unit area of pasture. Compared to clumps in rotationally grazed pastures, clumps in set stocked pastures have larger numbers of smaller tillers. Overall, the density of tillers per unit area of pasture may be the same under set stocked and rotational grazing, but plant survival and plant size are the key factors to consider and these are greater under rotational grazing.

- Perennial ryegrass persistence is much less responsive to 4- or 8-paddock rotational grazing systems than phalaris. Best-bet grazing management to improve perennial ryegrass percentage involves resting 8-10 weeks after seed-set and again after the autumn break.

### *4.3.2 Regional specific findings*

**North West Slopes NSW**

- Up to 70% of the annual rainfall in northern NSW is lost by evapotranspiration, of which evaporation can be a large component. One of the few ways that producers can trap this moisture in the soil and prevent it from being lost as evaporation and make it available for plant growth is by laying down litter (1.5-2.0 tonnes/ha or 2-3 handfuls per square foot) to form a surface mulch.

- Up to one-third of the total soil water content may be unavailable for use by most pasture legumes and grasses, since it is held by the soil particles at too high a tension for native and temperate grass plants to be able to extract it.

- In the root zone (50-80 cm) most pastures have low soil water content for most of the year, indicating that plants are often water stressed. Overgrazing in dry periods reduces the persistence of perennial grasses.

**Western Australia (Albany and Esperance regions)**

- Proximity to Tasmanian bluegums reduces herbage accumulation in annual based pastures but not kikuyu.

- Reduced herbage accumulation by annual pastures in competition with trees was mostly explained by lower soil fertility and moisture within the root competition zone.

- To minimise loss of pasture production within tree/pasture systems, tree belts where possible, should be planted North/South not East/West. East/West belts result in significant areas of shaded (South facing) pasture and the greatest loss of livestock production.

- Livestock producers that utilise their pastures efficiently will suffer dramatic losses in pasture and livestock production if they establish Tasmanian bluegum belts closer than 100 meters.

- It is essential to maintain a strong legume content in kikuyu pastures to provide winter/spring production and nitrogen inputs. This can be achieved through controlling red legged earth mites and heavy autumn grazing to provide space for germinating legumes.

### *4.3.3 Hunches*

- Rotational grazing or resting does not result in large increases in herbage accumulation.

- Deep rooted $C_3$ and $C_4$ perennial grasses will increase herbage accumulation in some seasons.

- Rotational grazing strategies aimed at production need to maximise the availability of green leaf (grass and legume) and require shorter resting periods of around 4 weeks (30 days).

- Robust sustainability indicators include the proportion of days in the year that a pasture possesses green leaf, and groundcover of $\geq$70%.

- Use of perennial pasture species in agroforestry systems will minimise loss of pasture and livestock production from competition with the trees.

### 4.3.4 Uncertainties

- The exploitation of apparent opportunities for manipulating pasture composition to suit specific production or sustainability objectives in whole farm systems is an exciting prospect but requires further research and on-farm development work to determine how best to implement appropriate grazing tactics.

- The need to determine the circumstances favouring the relative contribution to perenniality of increasing plant size versus seedling recruitment. While both mechanisms are most likely involved, the circumstances under which each mechanism operates would assist in determining the relative likelihood of success, and influence recommendations. The mechanisms for increasing perenniality should provide insight into the processes involved in pasture decline and weed invasion, and provide feedback into management strategies that counter the processes of pasture decline. Knowledge of plant dynamics *eg.* individual plant age would also assist our understanding of what represents a sustainable pasture.

- What are the rules for deciding when to move stock in flexible rotations?

- How much more can we improve utilisation of rainfall and soil moisture beyond that achieved in the SGS National Experiment?

- To what extent can we extend species findings beyond the local region surrounding a Site? For example can chicory or native grasses improve pastures in WA? and can a summer active perennial grass like kikuyu be incorporated in the East?

- To what extent can a combination of grazing tactics improve pasture production and stability beyond that achieved with a single tactic such as rotational grazing, and what are the general rules for knowing which tactics to employ when?

- Is it possible to develop a robust set of grazing rules that could be applied to a large number of pasture types to achieve the desired level of pasture production and stability?

- For the lesser-researched perennial grasses we need to improve our understanding of how they function to improve their management.

- How can we combine perennial legumes or broadleaves with perennial grasses to improve production?

- How can remote sensing (eg satellite technology) improve pasture management by providing farmers with key parameters such as pasture quality, quantity and growth rates?

- Would a better understanding of the relationship between leaf area index and pasture growth lead to improved herbage accumulation and water use efficiency?

- How can perennial pasture establishment be made cheaper and simpler?

- How can lost pasture production adjoining tree belts be recovered?

### *4.3.5 Regional specific uncertainties*

**North West Slopes, NSW**

- What other techniques (slashing, mob stocking, and chemical defoliation) can graziers use to strategically convert standing dead to litter, particularly pre-summer?
- How to maintain pasture production in sporadic rainfall environments? Ie. with no clearly defined growing season.
- If you increase litter on the soil surface do you also increase soil microbes and pasture production?

**Western Victoria**

- How to extrapolate grazing management insights from phalaris to rye grass.

**Western Australia**

- Are there tufted $C_4$ warm season perennial grasses that are superior to kikuyu in forage quality, herbage accumulation and for cattle production.
- How can kikuyu pastures be run as a high input system?
- Could desirable perennial broadleaf pasture species be useful for grazing systems in southwest WA?

# 5. EXTENT TO WHICH THE DATABASE AND MODEL HAVE CONTRIBUTED TO ANSWERING THEME QUESTIONS

## 5.1 SGS Database

The SGS Database was an essential tool in the process of data collection and interrogation leading to the Pasture Theme cross-Site analyses. The individual Site databases provided a one-stop-shop for the post-docs to access climate, soil, pasture and animal information required for these analyses. The consistent format of the data provided by the database framework was particularly important in facilitating data extraction and analysis in the Theme context. The incorporation of complex routines (eg the metabolisable energy queries used to estimate animal intake) highlights the potential of the database.

## 5.2 SGS Pasture Model

The SGS Pasture Model has been used extensively in the Harvest Year to answer Theme questions, including the effects of grazing management and pasture type (phalaris, kikuyu, annual ryegrass and redgrass, all grown with subclover) on annual herbage accumulation at

each NE Site, using long-run simulations (1971-2001) with SILO climate datasets. These results are published in the attached Pasture Theme paper (Sanford *et al.* 2003). Use of the model confirmed the cross-Site analysis and findings of the Western Victoria site that there was limited opportunity to increase herbage accumulation by adopting different grazing management strategies. However the model alone was used to examine to impact of pasture type on herbage accumulation and the outcome suggested that deep rooted $C_3$ and $C_4$ perennial grasses could have increased herbage accumulation at some sites in certain years.
Further analyses using the model have investigated the seasonal growth pattern of the four pasture types (Fig 4) and effect of soil type on annual herbage accumulation (Fig 5) of phalaris/subclover pastures at each NE Site.

Although the total annual herbage production of redgrass pasture was low relative to the other species for the southern Sites (Sanford *et al.* 2003), this species showed the most summer activity (Fig 4) suggesting it could be a useful addition to pasture types lacking summer activity.

The analysis of herbage accumulation of phalaris/subclover pastures on four soil types showed that production was limited on the sandy soil. At each Site there was more surplus water on the sandy soil, lost primarily through drainage, which limited pasture growth.

## 5.3 Comments from individual Theme members

- The adoption rate on these tools provided by SGS was slow and Themes really did not fully embrace the use of the database until the post-docs were appointed or the model until well into writing the Theme papers for the Special Issue. These will have to be adopted earlier in subsequent programs, perhaps through pre-experimental modelling or workshopping the use of these tools to solve the Theme questions.

- The database provided a tool to accommodate and manage a large amount of data, such as collected in the Pasture Theme. Common database routines enabled standard data extraction processes. The model could have been used more to investigate further the effect of different management regimes on pasture production. The model allows important interactions within the system to be understood. For example critical thresholds and timing of pasture herbage mass, below which production may crash, and above which production remains satisfactory; and the rate of leaf turnover from green leaf to litter. This has implications for increasing organic matter, decreasing bare soil evaporation, increasing nutrient cycling, better soil structure etc.

- Without question the database made the extraction of quality data by the post-docs for cross-Site analysis much quicker and easier. Improving the process of interacting with the database would require friendlier data entry, the ability to build your own queries in the graph package easily and a simple way to manipulate data eg plug data from tables into a formula and place the result in a new table.

- While the model successfully contributed to answering the Theme questions much of its potential was not fully realised because it took a long time to develop and confidence in model output was lacking. One improvement to the model would be the ability to graph the output of long term simulations within the package rather than having to export and then manipulate the data before graphing in Excel. Another would be the ability to simulate all the paddocks in a rotational grazing system at the same time.

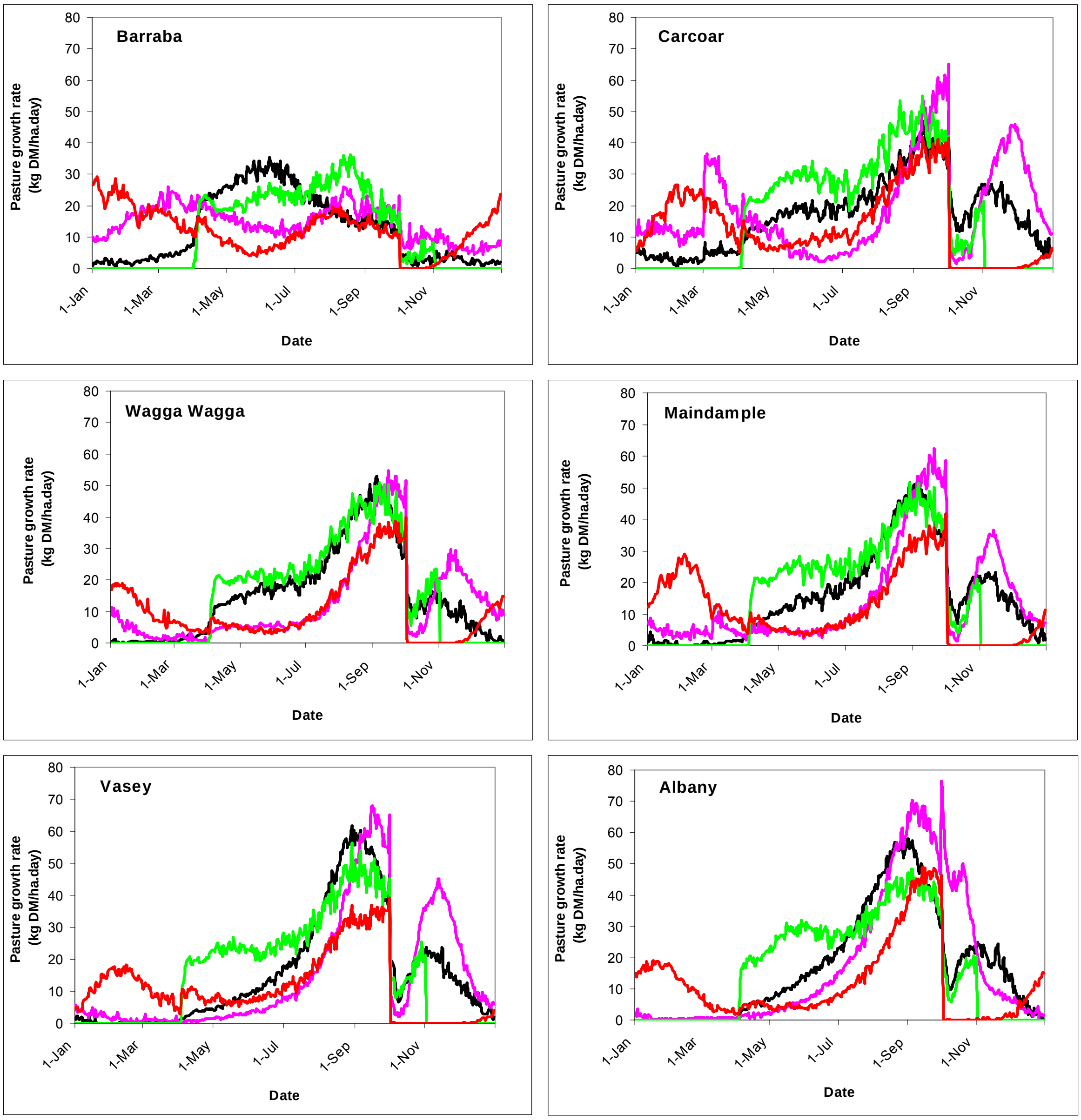


**Figure 4:** Mean daily pasture growth rates (kg DM/ha) for phalaris (black), kikuyu (pink), redgrass (red) and annual ryegrass (green) pastures grown with subclover at the six NE Sites, as simulated by the SGS Pasture model (1971 – 2001). The same soil type was used for all Sites, based on the duplex soil at Vasey.

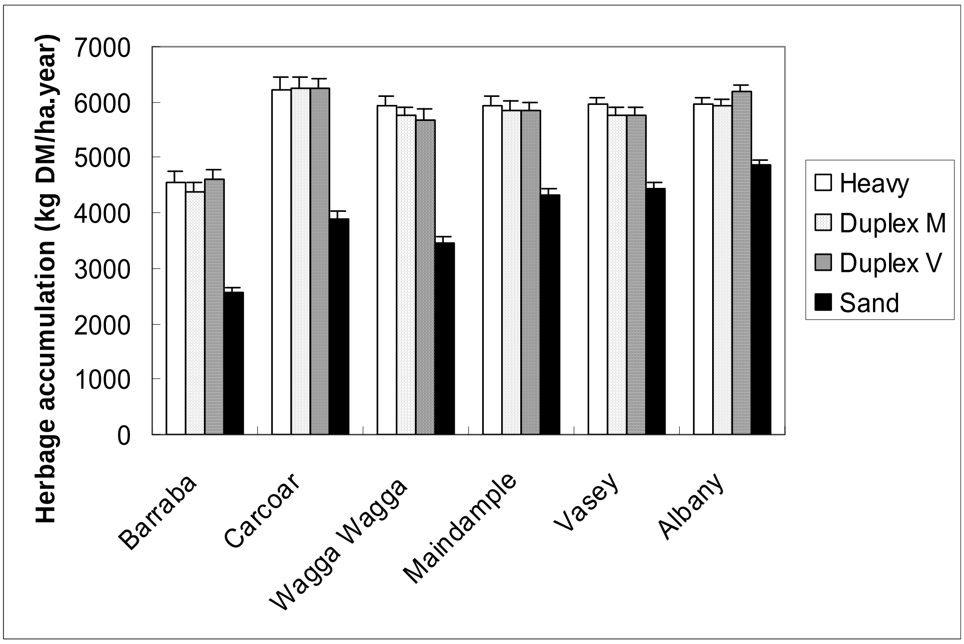


**Figure 5:** Effect of soil type on mean herbage accumulation (kg DM/ha.year; 1971-2001) of a phalaris/subclover pasture at each SGS NE Site, as simulated by the SGS Pasture model. Y-error bars indicate the standard error of the mean.

# 6. PUBLICATIONS

In addition to the scientific publications listed below the Theme published numerous articles for publications such as Prograzier and Tips and Tools.

## 6.1 Publications published

Lodge, GM, Murphy, SR (2002) Ground cover in temperate native perennial grass pastures. II. Relationships with herbage and litter mass. *The Rangeland Journal* 23,

Murphy SR, Lodge GM (2002) Ground cover in temperate native perennial grass pastures. I. A comparison of four estimation methods. *The Rangeland Journal* 23,

Sanford, P., Gladman, J. and Cransberg, L. (1997). Sheep production on an annual and perennial pasture in southwest Australia. In 'Proceedings XVIII International Grassland Congress', Canada.

Sanford P, Kemp D, Lodge G, Garden D, Grimm M, Graham J (1998) Pasture theme protocol. In 'Themes and experimental protocols for sustainable grazing systems'. (Ed. GM Lodge) pp. 12-29. Meat and Livestock Australia & Land and Water Resources Research and Development Corporation, Occasional Publication No **13/98**.

## 6.2 Manuscripts in preparation

Lodge GM, Murphy SR, Harden S (2003*a*) Effects of continuous and seasonal grazing strategies on the herbage mass, persistence, animal productivity and soil water content of a

Sirosa phalaris – subterranean clover pasture, North-West Slopes, New South Wales. *Australian Journal of Experimental Agriculture* **43** (*in prep*.)

Lodge GM, Murphy SR, Harden S (2003*b*) Effects of grazing and management on herbage mass, persistence, animal production and soil water content of native pastures. 1. A redgrass-wallaby grass pasture, Barraba, North-West Slopes New South Wales. *Australian Journal of Experimental Agriculture* **43** *(in prep.)*

Lodge GM, Murphy SR, Harden S (2003*c*) Effects of grazing and management on herbage mass, persistence, animal production and soil water content of native pastures. 2. A mixed native pasture, Manilla, North-West Slopes New South Wales. *Australian Journal of Experimental Agriculture* **43** *(in prep.)*

Sanford P, Cullen BR, Dowling PM, Chapman DF, Garden DL, Lodge GM, Andrew MH, Quigley PE, Murphy SR, King WMcG, Johnston WH, Kemp DR (2003) SGS Pasture Theme: effect of climate, soil factors and management on pasture production and stability across the high rainfall zone of southern Australia. *Australian Journal of Experimental Agriculture* **43** (in prep.)

## 6.3 Planned publications

There are no plans for future Theme publications, the following are planned Site papers relevant to the Theme.

Lodge GM, King KL, Murphy SR (2004) Litter in grazed sown and native pastures on the North-West Slopes of New South Wales. 1. Seasonal variations in quantity and quality. Australian Journal of Experimental Agriculture. (ms due 31 June 2003)

Lodge GM, King KL (2004) Litter in grazed sown and native pastures on the North-West Slopes of New South Wales. 2. Decomposition rates. Australian Journal of Experimental Agriculture. (ms due31 June 2003)

Sanford, P., Greathead, K., Gladman, J. and Boultwood, J. (2004). Tree-pasture interaction and its implications for livestock production in the high rainfall zone of southwest Australia. 1. Pasture and trees

## 6.4 Papers that could be written but for which there are no plans

- Further exploration of the Theme questions using the SGS Pasture Model and GrassGro.
- Comparison of a range of techniques used within the SGS National Experiment to estimate pasture growth rate.

# 7. CHALLENGES AND OPPORTUNITIES

## 7.1 Challenges

- Identification of productive and stable perennial pasture species that can significantly reduce groundwater recharge.
- Grazing systems that optimise the use of a range of tactics (rotational grazing, resting, set stocked) to achieve a particular pasture/livestock objective.
- Test the hypothesis that deep-rooted $C_3$ and $C_4$ perennial grasses can increase herbage production.
- Further use of modeling to determine optimal pasture management for production, stability and economics.
- Further investigation of the principles developed by the Theme as to how they apply to specific pasture types.
- Closer examination of the role of pasture litter in the production system and its implications for nutrient cycling, evaporation control, build-up of organic matter.
- Understand the plant ecology that drives the spatial and temporal dynamics of real pastures so to enable more ecologically-based management.

## 7.2 Opportunities

- Theme team could assist in the development of the new program to replace SGS, and develop a research proposal to submit to the new program or other sources of funding.
- Further cross-Site analysis and publications.

# 8. ACKNOWLEDGMENTS

We thank the researchers and producers involved in the SGS National Experiment for their contribution of data and ideas. Support for the Theme was provided by Meat and Livestock Australia, Land and Water Resources Research and Development Corporation, the Meat Program Agriculture Western Australia, Murray Darling Basin Commission, Natural Resources and Environment Victoria, NSW Department of Agriculture, University of New England and Melbourne University.

# 9. THEME MEMBERSHIP

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# 10. FINANCIAL STATEMENT

## 10.1 Funds administered by Department of Agriculture

| Year | Credit ($) | Debit ($) |
|---|---|---|
| 1997/98 | 7,500 | 0 |
| 1998/99 | 7,500 | 15,000 |
| 1999/00 | 7,500 | 0 |
| 2000/01 | 7,500 | 0 |
| 2001/02 (Harvest Year) | 10,000 | 7,919[A] |
| Total | 40,000 | 22,919 |
| Balance | | 17,081 |

[A] Payment of invoice submitted by Nutrient Theme Team.

## 10.2 Funds provided to Pasture Theme for Post-doctoral position at University of Melbourne.

*Note that the following budget does not include the Animal Theme component.*

| Budget item | Debit ($) |
|---|---|
| Salaries and on-costs | 24, 148 |
| Travel | 3,398 |
| Operating | 3,451 |
| Total | 30,998 |

# 11. VALUE-ADDED BY THE HARVEST YEAR PROCESS

## 11.1 Value added to Theme findings

- Without the harvest year there would not have been any major use of the model.

- Overall, I think that the Harvest Year added value to the Theme, in that the HY enabled collation of thought and findings. However, I believe that the Harvest Year would have achieved more had all Sites completed experiments and as a minimum, undertaken preliminary data analyses before the Harvest Year began. This would have assisted clarity of thought and enabled further progress and integration.

- The data set available for analysis in the Harvest Year was larger and of better quality than historical data sets. The cross-Site analysis was far more thorough with many different approaches explored. As a consequence the Theme findings contained greater insight into how soil, water, management and plant species drive pasture production and stability.

## 11.2 How much have the Theme findings changed from last year's report?

Last year's findings were preliminary but proved to be accurate once the full analysis had been completed. The major change came from additional insights into what drove pasture production and stability (eg, using soil stored water rather than annual rainfall) plus refinement in terms of optimising factors for example the analysis suggests that stocking rates of between 15 and 23 dse/ha result in optimal herbage accumulation.

## 11.3 What is the added confidence in the findings?

Confidence in the findings has increased since there has been more time to analyse and understand the data and so provide a more valued interpretation.

## 11.4 What added insights/understandings have been achieved?

- One new insight would seem to be that "benchmarks" of kg DM/ha of pasture grown/mm of rainfall do not work across varying climatic and pasture zones and that effective rainfall or length of growing season is a much more realistic indicator.

- Drivers of pasture production and stability that had been established at local or regional also operate across the whole of the HRZ and can be proposed as principles.

- Rotational grazing or resting is unlikely to result in substantial increases in annual herbage accumulation.

- The addition of deep-rooted $C_3$ and $C_4$ perennial grass to pastures in the HRZ may increase annual herbage accumulation.

- Grazing management is the most powerful tool producers have for manipulating pasture composition.

## 11.5 How much more rapidly have the Theme's products been produced than would have been the case without a Harvest Year?

- At least 12 months was the general consensus however, it could have been as long as 2 to 3 years or never.

## 11.6 What value was added by the post-docs?

Brendan has done a good job of taking on the difficult task of the across-Site statistical analyses of the data. The post-docs also provide an independent, “third party” bridge to make accessing all of the data from the Sites a simple and straight-forward process.

Great value in that the post-docs allowed a central focus for the Theme tasks and a core stability to the process. The post-docs may have been aided by being on-board at an earlier stage.

### 11.7 In hindsight, how could the Harvest Year have been made more effective?

- We should have started it a lot earlier and allowed the researchers to have more of a data focus than a Harvest Team focus.
- Site experiments and data analyses already completed prior to the Harvest Year (as was the original plan). Thus, major results from Sites could be integrated through the Theme and Harvest Year process.
- The SGS Model, Database and Site data should have been ready from day 1 of the Harvest Year.
- Theme members need to be able to dedicate time to do the work of the Theme during the Harvest Year rather than continue with Site work.

## 12. EFFECTIVENESS OF THE THEME PROCESS IN THE SGS R&D ‘PARADIGM’

- The Theme process has effectively provided across-Site principles that I believe have moved forward our understanding of grazing systems in the HRZ. The process however did not find universal support amongst researchers because they were unsure what was expected and put most of their effort into the Site experiments.
- The Theme concept was a very good idea that met the “vision” of the producers in the Planning Group and SGS management. Unfortunately, it was slow to be embraced by most researchers who were “Site focussed” and so not committed early enough to making sure that the Themes worked.
- I believe that all Themes struggled to achieve the lofty heights that could have been attained. To achieve more, the Themes really need a strong goal and target, with dedicated and enthusiastic leaders behind them. Perhaps that would require Theme leaders to be independent of the Sites, so that the Themes can be focussed upon without the distraction of Site issues (The Pasture Theme convener was also the WA Albany Site leader, and the demands (and loyalties) of these two roles were difficult to manage). Perhaps further incentive is also required for Theme leaders to recognise the importance of their role.

# APPENDIX 1:  PASTURE THEME PAPER

Pasture Theme Paper as submitted to Australian Journal of Experimental Agriculture, November 2003.