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The Sustainable Grazing Systems National Experiment. 2. Scientific outcomes and effectiveness of the research and development processes

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Abstract. The Sustainable Grazing Systems (SGS) National Experiment used 13 innovative research and development integrating processes to combine 6 diverse research sites across the southern high rainfall zone into a single, integrated experiment. Sites collected a common data set about the productivity and sustainability of grazing systems, so that issues beyond the site level could be explored. Essential to this approach were database and modelling tools that enabled across-site issues to be examined by a mix of conventional data analyses and modelling scenarios. This had not been previously attempted at this scale for the Australian grazing industries.

Major outcomes from the individual site and theme analyses were tabulated, providing a comprehensive summary of the SGS National Experiment research findings. Many of the research findings were new, and overall the SGS National Experiment improved our understanding of the processes operating in grazing systems and their interactions. The main conclusion from this substantive study was that graziers can use a combination of strategies to enhance the productivity and sustainability of their pastures, such as sowing deep-rooted perennial grasses, enhanced soil fertility, amelioration of low soil pH, and grazing methods that include rotation and rest.

Since the SGS National Experiment was itself an experiment, participants were surveyed to assess the integrating processes used, their implementation, and leadership and influence within the SGS National Experiment research group. Researchers rated the 13 innovative research and development processes for their potential to improve research and for the extent to which the processes were effectively implemented within SGS. The average potential score was 8.2 (out of 10). Four integrating processes had a potential score ≥9.0: the investment in a communication and product development year (the 'harvest year'); a common database structure across all sites; the use of themes to integrate across sites; and the use of protocols and minimum datasets to guide the research and data collection. We discuss possible ways to make these processes more effective. While 18 researchers had defined and active leadership roles from the outset of the SGS National Experiment, 2 researchers dominated the scientific influence and leadership.

Despite some implementation problems with the SGS National Experiment processes, internal and external reviews indicated that the SGS National Experiment met most of its goals and objectives. Because of the processes implemented, the SGS National Experiment framework has provided a new benchmark for conducting large-scale rural research in Australia.

Introduction

The SGS (Sustainable Grazing Systems) Program was an integrated research and extension program that operated across the southern high rainfall zone (HRZ, >600mm/year) of Australia. It comprised a national experiment, a training program, and a regional producer network (Mason *et al.* 2003*a*). The operation of the regional producer network was reported by Simpson *et al.* (2003) and Andrew (2003), while the impact of SGS on producers across the HRZ was reported by Allan *et al.* (2003). Mason *et al.* (2003*b*) provided a comprehensive, triple bottom line assessment of the SGS Program as a whole. This paper summarises the scientific outcomes from the national experiment, as well as an assessment of the effectiveness of the integrating processes used within the national experiment.

The background to the SGS National Experiment, its design and the methods used for data collection were described by Andrew and Lodge (2003). Briefly, the SGS National Experiment comprised an integrated network of 6 research sites across the southern HRZ from Albany in Western Australia to the North West Slopes of New South Wales. Sites focused on locally relevant issues.

Across-site analysis was underpinned by 5 themes (water, nutrients, pastures, animal production and biodiversity), a

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common set of measurements, a database structure and a simulation model.

Detailed findings for sites and subsites were reported by Sanford *et al.* (2003*a*) and McDowall *et al.* (2003) for Western Australia, Chapman *et al.* (2003) for western Victoria, Ridley *et al.* (2003) for north-east Victoria, Johnston *et al.* (2003) for the eastern Riverina region of New South Wales, Garden *et al.* (2003) for the Southern Tablelands of New South Wales, central Victoria and south-east South Australia, Michalk *et al.* (2003) for the Central Tablelands of New South Wales and Lodge *et al.* (2003*a*, 2003*b*, 2003*c*) for the North West Slopes of New South Wales subsites. Outcomes from the themes were presented for water (White *et al.* 2003), pastures (Sanford *et al.* 2003*b*), animal production (Graham *et al.* 2003), nutrients (McCaskill *et al.* 2003) and biodiversity (Kemp *et al.* 2003). Economic analyses were undertaken at the macro- and micro-level and a procedural tool developed to appraise the on- and off-farm impacts of different pasture and management systems (Barlow *et al.* 2003).

The approach adopted in the SGS National Experiment was to combine the best ideas relating to R&D processes into a new framework to provide a mechanism through which 6 independent experimental sites, representing a wide range of environmental conditions, could be linked to build on the individual site findings, and to explore issues beyond the site level. These integrating processes included themes (Mason and Andrew 1998; Andrew and Lodge 2003), common protocols for collecting data (Lodge 1998), a common database structure and format (Scott and Lord 2003), the SGS Pasture Model (Johnson *et al.* 2003) purpose built for the SGS National Experiment, and a sustainability economic analysis tool (Barlow *et al.* 2003). Collectively, they enabled across-site issues to be examined by a unique mixture of data analysis and modelling scenarios, at a scale not previously attempted in the Australian grazing industries.

Some of the individual processes used in the SGS National Experiment were not new. For example, producer involvement (e.g. Carberry *et al.* 2002), the use of protocols, e.g. as in the Temperate Pastures Sustainability Key Program (TPSKP) (Lodge and Garden 2000), the use of databases to empower research processes — for agroecological research data in USA (van Evert *et al.* 1999*a*, 1999*b*); for the TPSKP northern sustainability site (Scott *et al.* 2000*a*); for annual crop data (Hunt *et al.* 2001); for metadata about soil organic matter experimentation in Europe (Franko *et al.* 2002), examination of data using modelling (e.g. McCown 1982), requirement for minimum data sets, for example TPSKP climate data (Lodge and Garden 2000), economic analyses of experimental findings, e.g. as used in TPSKP for grazing method experiments (Scott *et al.* 2000*b*), and for the TPSKP sustainability sites (White *et al.* 2000; Scott *et al.* 2000*a*). However, in these examples the processes were used individually, while in the SGS National Experiment they were used collectively to combine the individual sites into a single national experiment.

This integration was further enhanced by introducing new processes and innovations during the design and implementation of the national experiment that have the potential to be incorporated in future agricultural R&D programs. These included: the selection of research teams (which then collectively developed the research plans) rather than specific project proposals (Andrew and Lodge 2003); the use of pre-experimental modelling to assist experimental design (Simpson *et al.* 1998; Bond *et al.* 1997), and the development of themes to allow the examination of issues across the range of sites, effectively creating an integrated national ‘experiment’ (Andrew and Lodge 2003). Further initiatives that evolved during the implementation phase included the development of a biophysical model simultaneously with data collection and interactivity with researchers (Johnson *et al.* 2003). Part way through the data collection phase, hunches (‘best bets’) about major research outcomes were used in advance of thorough data analysis to fast-track the extension of results to progressive producers (Andrew and Lodge 2003). In addition to the planned 5 years of the program, a ‘harvest year’ (Mason *et al.* 2003*a*) was funded to facilitate the scientific publication, product development and extension process using data sharing protocols. It was the combination and evolution of these processes that made the SGS National Experiment unique and therefore an ‘experiment’ in its own right.

Social processes also played an important part in unifying disparate organisations, disciplines and individuals to give shape to the SGS National Experiment (Price 2003), complementing the intellectual, methodological and experimental tools. Processes such as the use of a research executive, establishment of theme teams and the conduct of reflective forums (Andrew and Lodge 2003) helped gel the human dimension of the SGS National Experiment, while recognising its social and cultural diversity.

This paper summarises the scientific outcomes of the site and theme findings in the SGS National Experiment, considers their likely impact on production and environmental quality, and evaluates the effectiveness of the R&D processes that were used. The hypothesis being examined was that the range of innovations used in the national experiment was able to deliver new R&D outcomes efficiently and cost-effectively, and therefore set a new benchmark for R&D programs. These outcomes were also assessed by Mason *et al.* (2003*b*) in relation to defining a sustainable grazing system; indeed we recommend that Mason *et al.* (2003*b*) be read in conjunction with this paper in order to assess the combined impact of the national experiment and other components of SGS.

Since the SGS National Experiment was a sociological as well as a scientific undertaking, some findings about patterns of leadership and influence within the SGS National

Experiment researchers are also presented. Participating scientists in the national experiment assessed the actual and potential value of each of the 13 R&D processes used. These are presented, together with comments on how these processes may have been improved. Finally, we conclude by examining how well the SGS National Experiment achieved its goals and objectives, which were outlined by Andrew and Lodge (2003).

Materials and methods

Site and theme outcomes

The main research findings were summarised from the site and theme papers listed in the Introduction, from a summary prepared by theme conveners (Sanford *et al*. 2003*c*), and from notes made by the theme conveners about the implications of the theme findings. We used 2 questions to assist in interpreting this information: (i) what new information was generated from the SGS National Experiment and how reliable is it and (ii) what previous information was confirmed, or refuted by the SGS National Experiment?

Surveys of SGS National Experiment participants about R&D processes

The 24 most active participants in the SGS National Experiment (including 2 from the SGS Management Team) undertook a written survey in August 2002 (at the end of SGS and when site and theme papers were being finalised) to assess the potential and actual impact of the 13 processes used within the SGS National Experiment. This was the group with an intimate knowledge of the internal workings of the national experiment, who could therefore 'reflect back' over the program and draw informed conclusions. For each process, participants were asked to give a score out of 10 for: (i) what was the potential for this process to make a difference? (i.e. to what extent was this a good idea worth adopting in future programs; and (ii) what was its actual impact in the SGS National Experiment? (i.e. how well was it implemented in SGS?).

Respondents were also invited to provide written comments. The 13 processes surveyed (in approximate chronological order of implementation) were: (i) selection of teams rather than experimental projects; (ii) producer involvement; (iii) design of the SGS National Experiment as an aggregation of disparate experiments; (iv) use of data collection protocols and minimum data sets; (v) pre-experimental modelling; (vi) use of themes to link across sites; (vii) co-development of the SGS Pasture Model with the experimentation; (viii) use of the SGS Pasture Model to explore and understand data; (ix) use of a common database structure; (x) publication and data sharing protocols; (xi) Providing producers with early 'hunches' from the research; (xii) developing an economic analysis framework; and (xiii) the SGS Harvest Year.

The survey also asked, 'With hindsight, what are the things you would do differently if you were implementing the SGS National Experiment over again?' Researchers could nominate up to 3 issues that they would have approached differently (i.e. there was no list provided) and weight them so that the total score added up to 5 (i.e. if only 1 issue was chosen then it scored 5; if 3 issues were nominated they could have been scored 3, 1, and 1 or 2, 2, and 1; etc). Survey findings were discussed at a meeting of SGS National Experiment researchers (19–20 September 2002) to gain a better understanding of how the SGS National Experiment could have been implemented more effectively.

As part of examining process 11, we also investigated how well researchers' hunches (as presented to a SGS national forum in March 2000) compared with findings reported in the site and theme papers listed in the Introduction. To do this, hunches were extracted from a report of the forum, and sent to the site leaders to compare with their analysed site findings (using a scale of: +3, hunch verified by subsequent data collection and analysis; 0, the hunch was neither verified or refuted; –3, hunch refuted by subsequent data and analysis; and NA, the hunch was not applicable to their site data).

Leadership and influence among the SGS National Experiment researchers

As part of the research reported by Price (2003), key SGS National Experiment participants were surveyed separately in April 2002 with the following questions: (i) who among the SGS National Experiment researchers do you consider have been the most influential in the group (name up to 5 if you like); (ii) what were the attributes of these individuals that made you select them; and (iii) for each of your selections, do you consider that they played a leadership role in the SGS National Experiment?

The survey group comprised the site leaders, theme conveners, 2 post-doctoral support staff, key scientific support (modeller, database and economics teams), and SGS management. Individuals defined 'influence' and 'leadership' for themselves. The survey was sent to 27 individuals (16 respondents). The number of selections each individual received for influence and leadership was determined, together with the number of times different attributes were mentioned.

The survey made an assumption that leaders were likely to be a subset of influencers rather than the other way around, and that traits of leadership might be inferred from a larger pool of influence traits. This was done to avoid respondents falling back on traits stereotypically associated with leadership. It also reflected the work of Oxley (1978), who in studying groups associated with rural Australia showed that leaders tend to possess a subset of influence traits — a subset largely based on the non-legal and non-authoritative drivers of influence.

Results and discussion

Scientific outcomes

Detailed outcomes from the SGS National Experiment sites and themes have been reported in the papers outlined in the Introduction. The tabulated results (Tables 1, 2 and 3) provide a comprehensive summary of the main findings and so an overview of the scientific outcomes from the SGS National Experiment.

Sites. Of the 65 findings listed for the sites (Tables 1 and 2), 52 (80%) were considered to be new information for the southern HRZ and 20% were reconfirmations of what was previously known. 'New findings' included information that was unexpected (e.g. differences in soil water content between degraded and perennial grass-based pastures of <2.5 mm/year at Nundle) and findings that had not previously been shown to have wide application. Reconfirmations were consistent with knowledge from other grazing studies, and so were not entirely unexpected (e.g. perenniality of native pastures increased with resting and declined with increased stocking rate at Carcoar). It is important to note that the SGS National Experiment was not designed to generate radical findings, but to explore how to increase the sustainability, productivity and profitability of mainstream grazing enterprises. Furthermore, treatments were not imposed to the point where the pasture resource was totally degraded; rather pastures were generally rested from grazing when pasture availability was low.

Themes. Many of the theme findings (Table 3) were also new (as defined above), but the power of these findings was

Table 1. Major outcomes from SGS National Experiment sites or sub-sites predominantly based on native and naturalised perennial grasses

Data are a summary of the treatment effects on herbage mass (HM, kg DM/ha), species composition, animal production (liveweight change and wool production, kg/head and, stocking rate, number per ha), and soil water expressed as soil water content (SWC, mm) or soil water deficit [SWD, as defined by White *et al*. (2003)]. Findings that are new information are denoted as normal text and previous findings that have been confirmed are denoted in italics

Site or subsite	Pastures		Animal production			Soil water
	Herbage mass (HM)	Species composition	Liveweight	Wool production	Stocking rate	
Barraba	Total HM decreased with continuous grazing (4 and 6 sheep/ha, no fertiliser). Increased with rotational grazing or continuous grazing with clover + fertiliser	*Most native perennial grasses not affected.* Redgrass[A] lowest with continuous grazing (4 and 6 sheep/ha, no fertiliser)	*Highest with continuous grazing (8 sheep/ha) and clover + fertiliser*	*Highest with continuous grazing (8 sheep/ha) and clover + fertiliser*	Not maintained in continuous grazing treatments (4 and 6 sheep/ha, no fertiliser)	Highest SWC in rotationally grazed (4 weeks grazing–12 weeks rest) and with continuous grazing (8 sheep/ha, clover + fertiliser), but differences <10 mm/year
Manilla	No significant effect of treatment on total HM compared with control	*No significant effect of treatment on perennial grass basal cover*	Lowest for 6 sheep/ha continuous grazed (no fertiliser) after spring 1998. Highest for 9 sheep/ha continuous grazed (clover + fertiliser)	Highest in 9 sheep/ha continuous grazed (clover + fertiliser) and rotationally grazed (4 weeks grazing–12 weeks rest) treatments (but only in 1999)	Not maintained in continous grazing treatments [6 sheep/ha, no fertiliser and 9 sheep/ha continuous grazed (clover + fertiliser)]	Significant but small differences in SWC (0–30 cm) between the control (continuous grazing 3 sheep/ha, no fertiliser) and the continuous grazed (6 sheep/ha, no fertiliser) and rotationally grazed (4 weeks grazing–12 weeks rest) treatments (<2 mm/year difference)
Carcoar	Total HM increased over time for the naturalised pasture with fertiliser and/or tactical management. Perennial grass HM increased by tactical grazing	Perenniality increased with resting and declined with stocking rate, and conversely for annual grasses	No naturalised pasture had capacity to finish lambs. Used chicory[B] to finish lambs raised on naturalised pasture	Increased with time, except unfertilised continuously grazed natural pasture. Continuous grazing produced more wool than tactical management	Remained static or declined slightly with time on most treatments	Increasing the perennial component in naturalised pastures reduced leakage from the root zone
Wagga Wagga satellite sites	Yass: Total HM not affected by treatments *Bendigo*: Total HM declined in all treatments except high input *Harrogate*: No trend in total HM over time	*Yass: Native perennial grasses (mainly Austrodanthonia spp.) declined and annual grasses increased as fertiliser rate increased* *Bendigo*: *Kangaroo grass*[C] *relatively stable*	Sheep production increased as fertiliser rates increased at Yass only	*Yass*: Similar for all treatments	*Yass*: *Stocking rate increased with increased superphosphate application and higher legume content.*	Not reported

[A]*Bothriochloa macra* (Steud) S. T. Blake. [B]*Cichorium intybus* L. [C]*Themeda australis* (R. Br.) Stapf.

Table 2. Major outcomes from SGS National Experiment sites or sub-sites predominantly based on sown pastures[A]

Data are a summary of the treatment effects on herbage mass (HM, kg DM/ha), species composition, animal production (liveweight change, kg/head; wool production, kg/head, and, stocking rate, number per ha), and soil water expressed as soil water content (SWC, mm) or soil water deficit [SWD, as defined by White *et al*. (2003)]. Findings that are new information are denoted as normal text and previous findings that have been confirmed are denoted in italics

Site or subsite	Pastures		Animal production			Soil water
	Herbage mass (HM)	Species composition	Liveweight	Wool production	Stocking rate	
Nundle	*Phalaris HM declined markedly with continuous grazing (12.3 sheep/ha).* Resting for 6 weeks in spring and autumn maintained phalaris	*Phalaris basal cover declined with continuous grazing* (12.3 sheep/ha) and saffron thistles increased	Highest in continuously grazed (12.3 sheep/ha)	Not significantly affected by treatment	Maintained in all treatments	Differences in SWC among treatments (0–30 cm) predicted to be <2.5 mm/year
Carcoar	Tactical management did not increase HM on cocksfoot/phalaris pasture. Chicory produced less HM than sown perennial grasses	Perenniality decreased with time but perennial grasses still made up >60% of HM	Highest lamb production to mid-February on sown perennial grass pasture (416 kg LW/ha), but heavier lambs produced on chicory (47 kg LW/head) that met export sale weight by mid-February. Lambs produced on sown pasture had to be finished on chicory to export specification\	Ewes grazing tactically managed sown pastures produced more wool (0.25 kg/head) than continuously grazed	Highest on continuously grazed (17.7 to 21 DSE/ha)	Sown pastures and chicory produced a greater SWD over summer than naturalised pasture. SWD positively correlated with perenniality
Wagga Wagga	Total and green HM higher in the phalaris catchment compared with the native pasture catchment in most seasons	Phalaris catchment dominated by weedy species in summer. Native catchment dominated by C_4 grasses	No marked decline with a periodic grazing strategy and high stocking rates	n.a.	*Carrying capacity of the phalaris catchment higher than native catchment*	In dry years the phalaris catchment developed a higher SWD than the native catchment
North-east Victoria	*Maindample*: Perennial grasses (mainly *Austrodanthonia* spp.) increased in the control but not the high or medium input treatments *Ruffy*: Perennial grass content reduced in the high input treatments	n.a.	*Maindample*: No effect of treatments on ewe liveweight *Ruffy*: Control, ewes 2–4 kg/head lighter No treatment effect on lamb weaning weight at either site	No effect of treatment at either site	n.a.	*Maindample*: SWD of phalaris pasture highest when applied P>22 kg/ha *Ruffy*: SWD highest for the *Austrodanthonia* and *Microlaena* pasture
Vasey	*Total pasture accumulation lowest on low fertility, set stocked treatments. Rotational grazing increased phalaris herbage accumulation, but decreased subterranean clover*	n.a.	Few significant differences in lamb production per ha	n.a.	High rates supported by rotational grazing and high fertiliser	SWD at the end of summer only differed by 12–14 mm
Albany	Competition from trees reduced annual herbage accumulation in annual pastures	No effect of trees	*Declined for sheep grazing annual pastures in summer. In summer and autumn kikuyu pastures maintained weight*	Lowest on annual pastures with trees. Highest on kikuyu pastures	Trees reduced carrying capacity. Highest on Kikuyu pastures, lowest on south facing annual pastures	*Kikuyu pastures used more water than annual pastures*. SWD below trees prevented pastures reaching field capacity in winter.
Esperance	Quality and quantity of kikuyu pasture in winter and spring was positively related to legume content	Kikuyu pastures had a lower amount of broadleaf weeds than annual pastures. *Annual pastures had a higher legume content*	At the same level of legume content cow liveweights and calf weaning weights were similar for kikuyu and annual pastures	n.a.	*Kikuyu pastures had a higher stocking rate than annual pastures in late summer and autumn.*	*Kikuyu pastures developed larger SWDs than annual pastures, particularly from November to March*

[A]Where native pasture species are mentioned, they formed part of controls. n.a., not applicable.

Table 3. Major outcomes from SGS National Experiment themes

Findings that are new information for the southern HRZ are denoted as normal text and previous findings that have been confirmed are denoted in italics

Pasture Theme: grassland herbage accumulation and livestock carrying capacity	
1	Annual rainfall was a poor predictor of both grassland herbage accumulation and livestock carrying capacity.
2	The empirical limit to water use efficiency for productive sown pasture is about 15 kg DM/ha.mm of annual rainfall.
3	Growing season length was a reasonably good predictor of both grassland herbage accumulation and livestock carrying capacity.
4	Much of the variation in herbage accumulation (other than due to growing season length) was explained by soil available P, the proportion of native species in the sward and stocking rate, together with interactions with other factors such as legume content.
5	Carrying capacity was affected by soil available P, soil pH, grazing method (mainly strategic resting, defined as livestock grazed outside the experiment to rest pastures), legume content and growing season length.
6	Changing from set stocking to rotational grazing reduced the need for supplementary feeding, particularly at high stocking rates even though it did not result in large increases in herbage accumulation.
7	Sown pastures based on 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. Additional gains in production and sustainability could be obtained by ensuring an adequate legume component, including a C_4 perennial grass and ameliorating soil acidity.
Biodiversity & Pasture Themes: plant diversity and grassland stability	
1	More than 200 plant taxa were recorded over the experimental period (1997–2001).
2	About one-third of these (i.e. about 70 taxa) were native perennial grasses, most of which persisted even when fertilised and oversown with introduced species.
3	Where grasslands were less intensively used (average herbage mass >2000 kg DM/ha), the number of native species increased by 1–2
4	*Where grasslands were more heavily grazed, the number of native species tended to decrease*.
5	Native grasses made a higher contribution to herbage mass than other native species, most of which were forbs.
6	There was a tendency for herbage accumulation to decline as total species richness increased.
7	Where the herbage mass was maintained between 2000–4000 kg DM/ha, species were maintained and productivity was optimised.
8	Perennial grass content and basal cover were both significantly influenced by growing season length, grazing method (set stocked, rotation, and strategic rest) and an interaction between stocking rate and soil pH.
9	*Perennial grass content was increased by both rotational grazing and resting*.
10	*Legume content of grasslands increased in response to set stocking and increased stocking rate*.
Water Theme: grasslands and soil water	
1	Kikuyu created the highest soil water deficit (SWD, the difference between the mean profile water content at field capacity and the amount of water in the profile at the time of measurement) — an increase of 55–71 mm when compared with pastures dominated by annual species.
2	Other perennial grasses, such as phalaris created more moderate differences in SWDs (18–45 mm more than annuals).
3	*SWD positively correlated with perenniality.*
4	*Trees (in either belts or parkland configuration) reduced the probability of surplus water in winter to zero in their immediate vicinity.*
5	*Plant root depth was crucial in decreasing deep drainage (long term model simulations).*
6	*Soil type affected SWD primarily through controlling the rooting depth of the vegetation, but it also changed the partitioning of surplus water between runoff and deep drainage.*
7	*Grazing method and grassland management had only a marginal effect on SWD.*
Nutrient Theme: nutrient loss and off-site impacts	
1	Simulated nitrate leaching was greatest for the annual pasture (range 34–58 kg N/ha.year), followed by phalaris (≤11 kg N/ha.year) then kikuyu (≤3 kg N/ha.year).
2	*Much higher acidification rates were estimated at southern sites than in northern NSW, due to the relatively low level of nitrate leaching likely in summer dominant rainfall environments coupled with lower stocking rates.*
3	The concentration of P in surface runoff was related to soil fertility at the 4 southern Sites.
4	Concentration of total P in surface flow from all sites exceeded the maximum accepted water quality guidelines for P trigger values for healthy streams.
5	Average N concentrations always exceeded the stream trigger levels even for native pasture treatments, often by 10-fold, yet there was no consistent relationship between level of intensification and the N concentration of runoff water.
6	Evidence of high spatial variation in surface runoff generation, implying opportunities to minimise catchment impacts by tailoring management to land capability.
Animal Production Theme: productivity and sustainability	
1	Different grazing methods significantly influenced productivity (as measured by carrying capacity; DSE/ha), but effects were not consistent across sites.
2	Over all sites, carrying capacity was significantly affected by soil Olsen P (+ve), soil pH (+ve), grazing management (resting, –ve), legume percent (+ve), and an index of growing season effectiveness (+ve).
3	There were generally positive relationships between increased carrying capacity (a measure of productivity), the probability of achieving a zero winter soil water surplus, and perennial grass content for contrasting treatments at each site, but this was not apparent with the combined site data. Nevertheless, the SGS NE included examples of grazing systems that combined high carrying capacity with a substantial perennial grass content and a low probability of a winter surplus.

their robustness, since the across-site analyses were supported by modelled interpretations. In this way, the SGS National Experiment provided a more complete understanding of components of grazing systems such as water movement in temperate pastures. This understanding emerged both from the experimental data and also by continual refinement of the SGS Pasture Model to incorporate processes not previously included, such as the interception of rainfall by the canopy and litter, and loss of effective rainfall by evaporation from plant surfaces before it reached the soil surface. The abilities of sown perennial tussock grasses such as phalaris (*Phalaris aquatica* L.) to influence water use and movement is now more clearly understood. These outcomes were consistent with previous findings (Ridley *et al*. 1997) and such species have the capacity to reduce deep drainage by one-half to one-third of that of annual pastures. Of the pasture species tested in the winter rainfall zone, only kikuyu (*Pennisetum clandestinum* Hochst. Ex Chiov.) was able to reduce deep drainage by >50% compared with annual pasture, while providing high pasture production. Where deep drainage was likely to be a major problem, plantation trees placed in strategic locations appeared to be the only feasible option to virtually eliminate it.

The relatively small effect of grazing system on pasture water use was not unexpected and was predicted in the pre-experimental modelling (Bond *et al*. 1997; Simpson *et al*. 1998). However, these effects may have been larger if the treatment effects had caused a marked decline in the perennial grass content, reflecting what often occurs in commercial practice. The strong relationships reported between actual runoff and ground cover (Lodge *et al*. 2003*a*, 2003*b*) or maximum runoff and biomass (Packer *et al*. 2003) suggested that grazing management may have a vital role in affecting the partitioning of excess water to runoff or deep drainage.

Encouragingly from an environmental perspective, highly intensified grazing systems appeared to be as sustainable as low-input systems (and much more profitable). Of concern, however, was the observation that medium levels of grazing intensification were possibly more risky because the nitrogen (N) input from legumes was higher than that required to meet the demands of the companion grasses and forbs. This demonstrated the sensitivity of these systems to changes in management when viewed holistically, and the small margins within which producers must manage to achieve a balance between different components of their grazing ecosystems.

Of greater concern were the concentrations of N and phosphorus (P) in surface runoff that exceeded accepted stream quality guidelines for both extensive and intensive systems (Anon. 2000; see also McCaskill *et al*. 2003). High concentrations of N in runoff appeared to be largely independent of management, suggesting that there was little a landholder could do to achieve these water quality targets.

The biodiversity findings are a first for Australian agriculture at this broad scale. Most biodiversity experiments are usually on a small scale [e.g. the pioneering grassland biodiversity work of Tilman (1982) was done in plots of 9 m^2], however, the SGS National Experiment represented the beginning of the incorporation of biodiversity objectives into a mainstream industry R&D program.

In particular, the research findings demonstrated the validity of 2 major assumptions underlying the SGS Program (Mason *et al*. 2003*a*): the importance of both perenniality and grazing management to maintain healthy and productive grazing systems. Perennial grasses provide forage over extended periods as well as assisting in the management of dryland salinity and soil acidity through better soil water management. While perennial tussock grasses reduced deep drainage by up to 50% compared with annuals in the SGS National Experiment, their ability to dry the soil profile was less than that of kikuyu and much less than that of trees. However, they do promote soil surface stability, reduce erosion, and maintain pasture stability and biodiversity of native plant species by reducing the presence of weedy species. The role of grazing management is discussed in detail in the concluding paper of this Special Edition (Mason *et al*. 2003*b*).

Overall, these research findings provide a better understanding of the 'drivers' of the processes and mechanisms in grazing systems in the HRZ of temperate Australia and how they respond to manipulation. The findings are positive, and provide graziers in southern Australia with the confidence to use deep-rooted perennials enhanced by applying fertiliser to ameliorate soil problems (e.g. pH and deep drainage) and grazing methods that include rotation or protracted targeted rest to enhance pasture productivity and sustainability. The findings also highlight the need to develop spatially sophisticated land use systems, involving grazing management in combination with other land uses, according to the capabilities and inherent hydrological characteristics of different land classes.

Influence and leadership within the national experiment research team

Six individuals were nominated by >30% of survey respondents as having a major influence in the SGS NE; 5 of those were also nominated by >30% of respondents as providing leadership (Fig. 1). Collectively, this group comprised 2 site leaders, 3 theme conveners and 2 individuals who were neither site nor theme leaders. Two of these individuals dominated both the influence and leadership nominations. Taking into account the size, structure and interlinking processes of the SGS National Experiment and that the formal leadership team of 18 researchers was in place from the outset (e.g. the 'Research Executive' comprising theme conveners, site leaders, modeller, database team, and other key site researchers), it was surprising that most of the leadership and influence was perceived by SGS

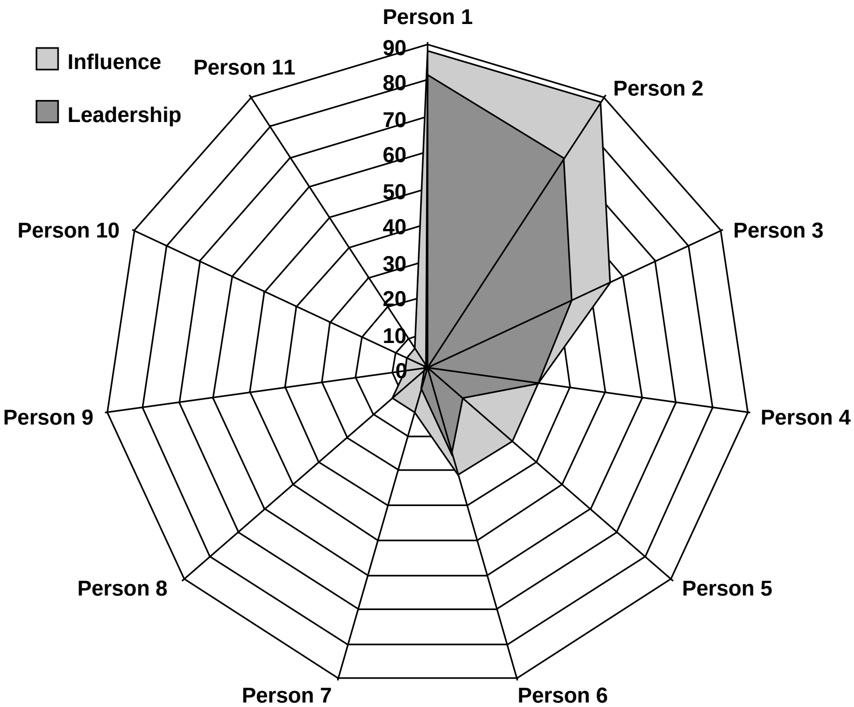


Figure 1. Patterns of leadership and influence seen in the SGS National Experiment. Values are the percentage of respondents who nominated each person.

National Experiment colleagues to be concentrated in such a small group. However, this finding is consistent with the Pareto principle that 20% of a group comprises 80% of its effectiveness (Maxwell 1993). While the survey focused on leadership and influence amongst the research group, the SGS Program coordinator and theme coordinator also had major roles in the direction of the SGS National Experiment (Price 2003).

Sixteen survey respondents identified 45 separate traits of the influencers. These traits were aggregated into like-categories and summarised (Fig. 2). The most frequently mentioned category was professional knowledge/experience

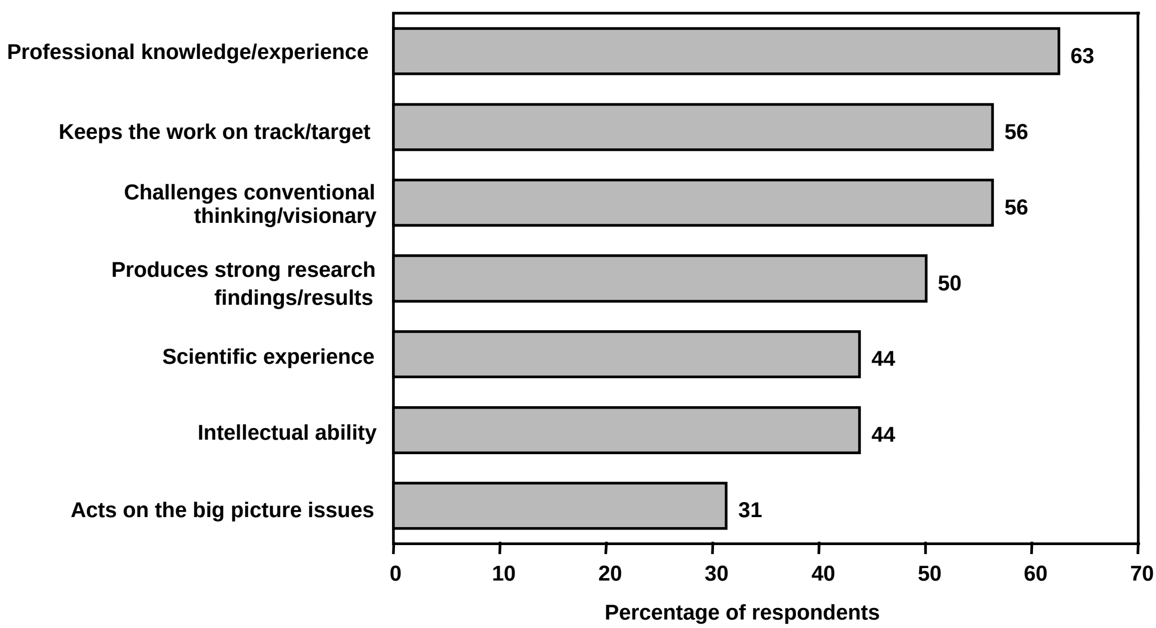
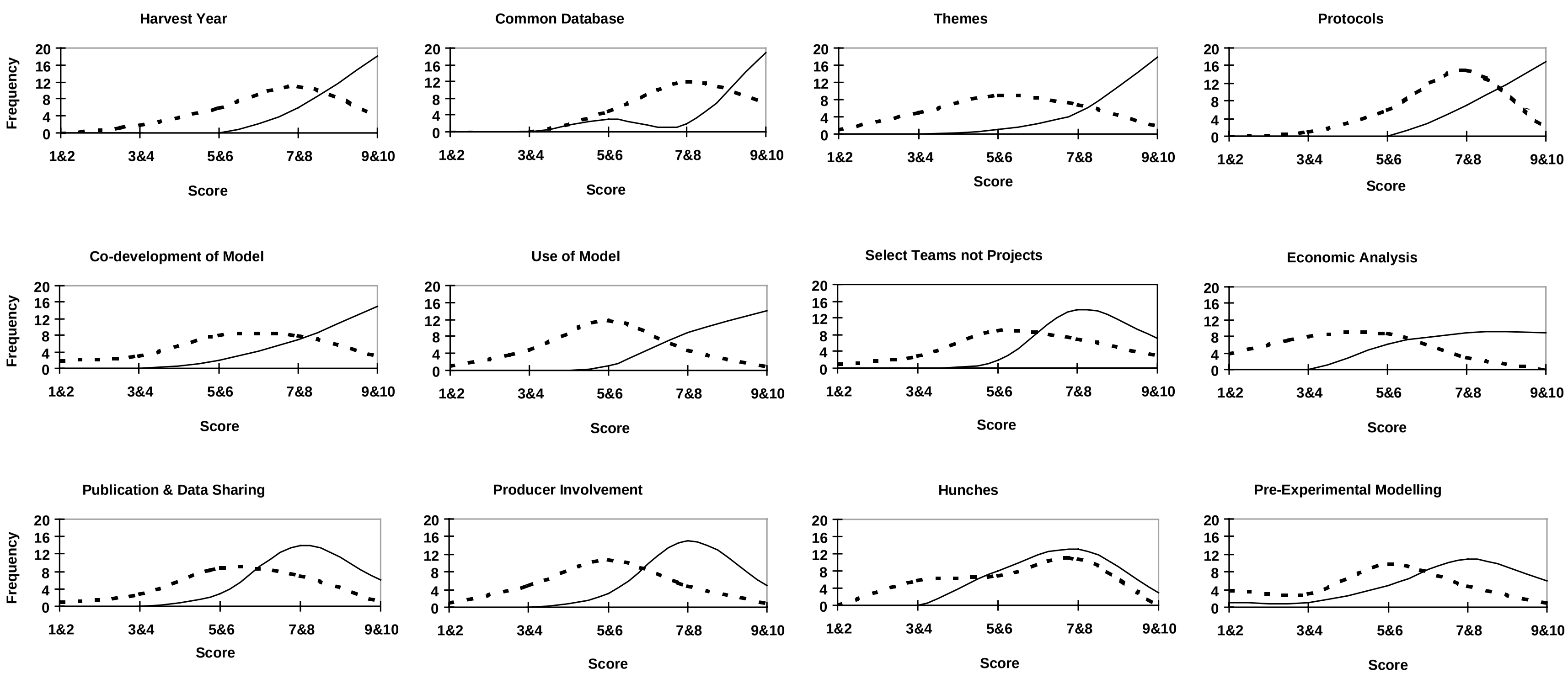


Figure 2. Most frequently mentioned influencer traits.



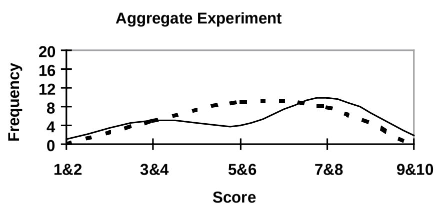


Figure 3. Frequency of responses (0–24) for each of the scores (1–10) of the potential (solid line) and actual (dotted line) impact for each of the 13 R&D processes used in the SGS National Experiment.

(10 of the 16 respondents, 63%). Comments relating to this category included: '…for his TPSKP experience in water balance', '…he has an excellent understanding of the pasture system', and 'solid experience'. Also frequently mentioned were 'keeps the work on track/on target' (56%), 'challenges conventional thinking/visionary' (56%), and, 'produces strong research results/findings' (50%). Comments here included phrases such as: '…constantly keeping the work on track', '… able to think outside the square', and '… strongly committed to delivering quality outcomes on time'.

Effectiveness of the R&D processes used in the SGS National Experiment

Survey data. Average potential impact scores were expressed as a 'score' out of 10, listed in declining order of 'potential' and presented graphically (Fig. 3). The scores for actual impact were expressed as a percentage of the potential score (Table 4). Suggestions for what researchers would do differently (Table 5) are presented with weighted scores summed for each category. Assessments for each of the 13 processes are presented and discussed together with quotations from researchers' written comments and from the September 2002 researchers' meeting. While 'before' and 'after' surveys are often used to quantify and evaluate change, the approach taken in this survey was to ask the researchers to 'reflect' back over the life of the national experiment and draw conclusions about both the 'potential worth' of each innovation, and the effectiveness of its implementation within SGS; it was not possible to have conducted a 'before' survey as most of the processes were not anticipated at the outset.

Researchers' ratings of the potential worth of the processes ranged from 6.2 to 9.3 (average = 8.2). Scores for actual impact within the SGS National Experiment averaged 6.0 (or 73% of their 'potential'), and there were many suggestions for improvement (Table 5). The sections below outline the assessment of each of the 13 innovations, in descending order of their perceived potential.

Harvest year (*potential score = 9.3*; *achievement = 77% of potential*)

The SGS Program was funded for 5 years to 30 June 2001. Instead of beginning a new R&D program from July 2001, the co-investors in SGS decided to fund an additional year (the 'harvest year') of data analysis and product development. A formal evaluation of the harvest year is presented by Mason *et al*. (2003*b*), but the comments below from the SGS researchers indicate substantial enthusiasm for this innovation:

> 'Provided the stimulus to bring the project to a conclusion with the findings being published on schedule.'
>
> 'A great innovation – giving researchers time to reflect on what they had measured.'
>
> 'Should become a 'mainstream' part of R&D project models.'

The concept of a harvest year has since been adopted in other R&D programs (Mason *et al*. 2003*b*). However, according to the SGS research team, its actual impact in SGS was well below its potential, since both the SGS management and the harvest year participants were 'feeling their way' with no established model to guide them. An external evaluation (Anon. 2002*b*) discussed by Mason *et al*. (2003*b*) concluded that the harvest year processes were superior to

Table 4. Mean score (maximum = 10) of survey respondents' assessment of the potential each of the 13 key R&D processes used in the SGS National Experiment, their rating of the actual impact of these processes (as a percentage of the potential score) and the improvement scores derived from respondents' suggestions for how the implementation of each process could have been improved

R&D process	Mean score		Improvement score[A]
	Potential impact	Actual impact (%)	
1. Harvest Year	9.3	77	3
2. Common database	9.1	85	4
3. Themes	9.1	63	22
4. Protocols, minimum dataset	9.0	78	8
5. Co-development of model	8.8	70	2
6. Use of model	8.8	64	3
7. Teams	8.1	75	4
8. Economic analysis	7.9	54	10
9. Publication, data sharing	7.8	74	3
10. Producer involvement	7.7	69	7
11. Pre-experimental modelling	7.3	67	3
12. Hunches	7.1	85	0
13. Aggregate experiment	6.2	94	9
Mean	8.2	73	

[A]Number of responses from researchers indicating that the implementation of this process could be improved in any future program. See Table 5 for more detailed comments.

the more traditional, linear R, D & E model in speeding up product development and creating time and 'space' for scientists to reflect, analyse and publish their data. The fact that this special edition of the *Australian Journal of Experimental Agriculture*, with 26 papers that cover the full range of activities in SGS, has been published within 2 years of the experiments concluding is strong evidence of the success of the harvest year. In addition, we consider that none of the theme papers would have been written without a harvest year, and certainly not in the comprehensive way of using both data and integrated modelling.

Common database structure (*potential = 9.1*; *achievement = 85% of potential*)

Each SGS National Experiment site had a purpose-built database (Scott and Lord 2003) to store, quality assure and analyse data. The structure and format of each site database was common, to facilitate across-site analyses thereby providing the potential for the 6 site databases to be combined into a single one.

The database was highly regarded by SGS researchers, and it had a high actual impact score.

> 'The database and the model are what made SGS successful.'
>
> 'Excellent — just needed more people to use it earlier.'
>
> 'By the end, the database was recognised by all sites as a superb instrument for sites, as well as providing the potential tool for across site analysis.'

Over the course of the SGS National Experiment the common database came to be regarded as one of its major strengths. However, its full potential may have been realised earlier in the program if it had been developed (and the

Table 5. What SGS researchers would do differently

These are total scores for volunteered responses, aggregated into the categories shown. Researchers could propose and weight up to 3 actions that they would want to do differently if SGS were repeated, weighted so the total was 5. (Refer to the text for further information)

Issue	Score
Themes	
Comments related mostly to strengthening the themes: establish themes at the outset — even before sites; specialist theme leaders who have the time and skills to devote to theme tasks; independence from site teams; draw from a wider group than the site teams; increase funding for across-site work; fund more basic theme research; specify data sharing up front; set more enforceable milestones for themes; provide dedicated theme support (i.e. post-doctoral fellows) earlier; undertake theme-based pre-experimental modelling	22
Economic analysis	
Strengthen the economic framework and analysis to ensure 'sustainability'; involve economists at design stage; avoid confusion between 'obscure' economics and net cash flow analysis of site results — clarify the roles of both at the outset; more involvement of resource economists in project designs	10
Aggregated experiment	
Comments related to how best to overcome the difficulties in across site analysis associated with the SGS National Experiment being an aggregation of different experiments: sharing expertise across site teams; include a common treatment at all sites; have more sites to reduce confounding; adhere to data collection protocols	9
Protocols	
It was suggested that protocols would have worked better if: compliance was actively enforced; database and model were adopted earlier; training was provided for unfamiliar techniques	8
Producer involvement	
There was a lack of synchrony between the establishment of the SGS National Experiment sites and the formation of the RPN. Suggestions for improvement included: establish producer groups before experimental sites; improve links between SGS National Experiment sites and producer sites	7
Other issues relating to the 13 processes in the survey (individual score ≤4)	22
The scores for improvements in all 13 processes surveyed are presented in Table 4. Only hunches received no suggestions for improvement	
Experimental design and scope	
The survey identified many ways to improve the design and/or the scope of the SGS National Experiment. Suggestions included: more Sites with cattle; more emphasis on wool production; more biodiversity measurements; explore options for heterogeneous sites; decrease the focus on conservative treatments; include some really adventurous, 'left-field' treatments	11
Management of the SGS National Experiment	
Suggestions for improving the management of the SGS National Experiment included: more meetings to discuss results; more full time researchers; a full time research coordinator; tighter oversight of the SGS National Experiment operation; a phased approach with longer term funding; and building the 13 processes into the SGS National Experiment at the start rather than during its operation	11
Other issues	
The focus of the remaining responses was on increasing the available resources (both financial and expertise) within the SGS National Experiment	5

scientists trained in its use) before experiments commenced. This may have prevented some sites setting up their own spreadsheet-based data handling systems. Conversion from these familiar spreadsheets to the unfamiliar database was often resisted, frustrating the use of site data by themes. Another inhibiting factor was that the database was not 'stable', but kept evolving in response to researchers' needs, and some key features were not implemented until late in the SGS National Experiment. Also, data sharing would have been easier had the individual site databases been combined into a single database early in the data collection phase.

Themes (*potential = 9.1*; *achievement = 63% of potential*)

The themes provide the real evidence of the value of trans-disciplinary approach that Cullen (2002) identified as being central for making progress towards developing solutions to our complex environmental problems. However, while the potential of themes was highly rated their actual impact was rated low, with a wide range of opinions of their value and role (Fig. 3). Suggested improvements to the SGS National Experiment (Table 5) were dominated by comments on how themes could have been made to work better. Researcher comments reflected this diversity of opinion:

> 'Because it was not part of the original design, researchers became over committed with site and theme responsibilities — nevertheless a great concept that should be included up front in new programs.'

> 'Great idea — many practical reasons why it is difficult to achieve.'

> 'It was a good idea! Parochialism, comfort zones and institutional structures got in the way.'

Themes were a significant innovation within the SGS National Experiment, which excited the participants, but the realised outcomes were less than the recognised potential. Overwhelmingly, the conclusion was that the commitment to sites was much stronger than the commitment to themes. Themes required a different type of thinking from that of formal experimental design and this was unfamiliar to most researchers.

Price (2002) also observed that the themes were developed after researchers had been contracted on a site-by-site basis. This incongruence of both timing and perception influenced the ability of some SGS National Experiment researchers to fully comprehend or adopt the notion of themes. This also highlights the difficulties for some scientists, who usually work in disciplinary isolation, of adapting to frequent interaction and stimulation across disciplinary boundaries, a difficulty Cullen (2002) suggested could be overcome with training in leadership and group processes. Arguably, the SGS National Experiment provided this training experientially, but perhaps not quickly enough. A common suggestion (Table 5) to assist themes to achieve their potential was to include specialist non-site members in each of the theme teams.

An unexpected benefit from themes was that by requiring each site to contribute to a minimum dataset, it promoted a level of within-site integration that may not have occurred otherwise. Themes also contributed to professional development as researchers learned new techniques, by being mentored by more experienced researchers from other sites.

Protocols and minimum datasets (*potential = 9.0*; *achievement = 78% of potential*)

To ensure compatibility across sites, experimental protocols were developed and published (Lodge 1998). These included specification of minimum datasets that all sites were 'obliged' to collect as well as a range of optional measurements.

Researchers regarded common measurement protocols as being pivotal to the success of the SGS National Experiment. However, their actual impact was only 78% of potential probably as a result of the less than full compliance. Procedures to ensure compliance were the subject of most of the suggested improvements (Table 5):

> 'Very strong positive impact.'

> 'There was non-compliance in some areas by all of us — sometimes due to personal preference, sometimes due to lack of information.'

> 'Minimum dataset was a good idea, and largely achieved.'

While protocols were considered to be a major process underpinning the operation of the SGS National Experiment, not all sites followed them rigorously, but this was only fully revealed when theme groups undertook the across-site analyses. A similar problem with non-compliance was noted in the TPSKP (Kemp *et al*. 2000). Although Scott and Lord (2003) indicated early detection of variations to the protocols by sites when developing their databases, there was no formal mechanism for feedback to SGS management. This was a substantial issue that will need to be addressed in any subsequent similar programs. Interestingly, there was wide agreement among researchers that compliance needed to be much more actively 'policed'.

Non-compliance was both active (site budgets claimed to be insufficient, prior commitment to other equipment) and passive (protocols ambiguous in the fine detail, inexperience with the technique). Despite these problems, the common database developed in the SGS National Experiment was sufficient to allow the theme groups to undertake across-site analyses in a relatively straightforward manner.

The idea of protocols has since been adopted by other programs (e.g. dairy farmlet studies) and the protocols for catchment impacts of the Dairy Research & Development Corporation, and the Sustainable Grazing on Saline Land project (part of the Land, Water & Wool Program of Land & Water Australia).

Co-development of model (*potential = 8.8*; *achievement = 70% of potential*)

At the start of the SGS National Experiment, it was decided to custom-build an appropriate biophysical model, by appointing an experienced modeller to develop the SGS Pasture Model in association with the site teams (see Johnson *et al.* 2003 for a detailed description of the model). All SGS National Experiment sites had the opportunity to be involved in the co-development of the model and the modeller was included in the 6-monthly meetings of researchers and theme teams.

Potential of the co-development concept was rated highly by SGS researchers, but actual impact was 70% of this potential. The wide range of actual impact scores reflected a marked difference in the way that different sites used the model; some interacted strongly with the model during its development, while others had little involvement. Comments from the survey reflected this dichotomy:

> 'Not being a modeller, the constant evolution of the model was a frustration.'

> 'Good idea and worked well.'

> 'Not quite as threatening as themes, but the process exposed technical and intellectual limitations within site teams.'

Co-development built strong ownership at some sites but, unfortunately, there was too little on-going engagement with the model by most of the SGS National Experiment sites for its co-development to be considered really effective (see the next section for more discussion of this point). Model development and enhancements reflected the input of the few researchers who actively engaged with the modeller. For co-development and use of the model to be effective, each site needed to have had a model 'champion' to work closely with the modeller. Development of the model in parallel with the research created some difficulties because it was never 'finalised', since the model was constantly being modified and upgraded over the period of the SGS National Experiment and into the harvest year.

Use of the model (*potential = 8.8*; *achievement = 64% of potential*)

While the potential impact from the use of the SGS Pasture Model was highly rated, the actual impact score for using the model was low and there was a strong concentration around the mid-score (Fig. 3). To overcome its low rate of adoption and use, a workshop was held in August 2000 for key members from each site that helped them to become more competent with using the model to explore data. As with the co-development of the model, there was a large diversity of opinion, reflecting variation in its use across the SGS National Experiment sites:

> 'Some sites were very model-orientated.'

> 'I think we have a great tool here, but I have not seen a huge amount of evidence that it has been used to its potential.'

> 'This was limited by there being only 1 model, which kept changing.'

While the model brought great strength to some sites, it was not seen as a relevant tool for others. At these latter sites its use was restricted by a lack of modelling expertise, and/or attachment to alternative models. However, the model was always intended to be one of the main tools for across-site analysis and its lack of actual impact probably reflected the lesser impact of the themes. In hindsight, use of the model (in conjunction with the database) to explore data may have been enhanced by undertaking a case study as an example for site and theme researchers to follow. This was considered early in the SGS National Experiment (using the sustainability datasets from TPSKP), but logistics (e.g. access to data, data in incompatible formats) prevented this from happening.

The major use of the model did not occur until late in the SGS National Experiment during preparation of the theme publications. After initial data analysis, theme groups agreed to use the model to further explore their research findings. Use of the model was also essential to overcome data confounding, thereby improving the credibility of those papers.

We predict that the SGS Pasture Model will be a significant legacy of the SGS National Experiment. It will provide an enhanced platform for pre-experimental modelling before any new research on grazing systems productivity and sustainability is undertaken in the HRZ of southern Australia.

Teams rather than research proposals (*potential = 8.1*; *achievement = 75% of potential*)

Traditionally, new industry-funded projects start with a specific, well-defined project proposal. By contrast, in the SGS National Experiment, initial advertisements and supporting material stated that 'We are seeking expressions of interest from research groups interested in developing and testing sustainable grazing systems … Please note that we are not looking for (and do not want) a project proposal.' The purpose was to select well-balanced teams that were then commissioned to collectively design the research program.

The potential for this process to have a substantial positive impact was reflected in its score (8.1, Table 4), but the actual impact did not realise this high expectation. The marked departure of this process from that which researchers normally experience in developing a new project was reflected in the comments from the survey:

> 'Bit unclear at the start what was expected of teams.'

> 'While the theory of selecting teams was sound, the reality was that teams had preconceived notions of their own experiments.'

> 'This approach is essential if the research is to reflect national rather than just local priorities.'

Selecting teams rather than projects allowed some flexibility in defining the SGS National Experiment, despite the preconceived notions and experimental plans some researchers brought to the planning and design process (Price 2002). It also encouraged a wider range of disciplines to be included within teams than might otherwise have been the case. While the impact of this process on some sites and their planned experiments were minimal (e.g. western Victoria), the changes were substantial for others (e.g. Carcoar and Albany).

Economic analyses (potential = 7.9; achievement = 54% of potential)

Economics was originally planned as a theme but since an economist was not a member of most site teams, an 'external' approach was taken. Initially, the economic approach was based on dynamic modelling to investigate optimal policy choices, but this did not provide sites with local economic analyses that they could present to producers. To overcome this some sites undertook their own analyses. A review of the SGS National Experiment (Johnson *et al.* 2001) highlighted the lack of a common approach across sites and recommended immediate action. The resulting framework for a combined economic analysis and sustainability assessment was developed by Barlow *et al.* (2003).

While economic analysis was rated as potentially having a large impact (7.9), its actual impact was only rated at 54% of this potential, the lowest of any of the 13 processes surveyed. The perceived failure of the initial analyses (based on dynamic programming) to deliver practical outcomes on time, and the late development of the economic/sustainability framework, combined to seriously lessen the impact of the economic analyses in the national experiment. Suggestions from researchers about ways to improve the SGS National Experiment (Table 5), and the comments below, highlighted these issues:

> 'Economics not taken seriously enough — I am like a cracked record on this!'
>
> 'Came a bit late in the day because of the poorly directed early economic work.'
>
> 'The final economic model was a poor substitute, focusing primarily on production issues, and treating environmental factors simplistically.'
>
> 'For lots of reasons, I think the final economic model will be one of the lasting legacies of the national experiment — however, it suffers from the weakness that it's for reporting to producers, not for reporting to scientists.'

Attempts at economic analysis were a source of tension within the SGS National Experiment. Again, different sites had their own preferred methods for undertaking economic analyses including specialised tools, and many were reluctant to change to a more basic, but uniform, net cash flow analysis. While change in approach from dynamic modelling to net cash flows and sustainability assessments created division, it provided a mechanism for comprehensive reporting to producers (in $/ha) and listing both positive and negative on- and off-farm effects. This approach to reporting sustainability issues (Barlow *et al.* 2003) is likely to prove a significant legacy from SGS, even though its subjective components lack the 'rigour' preferred by many researchers. Further, the economic analysis undertaken did not allow an analysis of the long-term (beyond 10 years) impact of management decisions.

Publications and data sharing protocol (*potential = 7.8*; *achievement = 74% of potential*)

Data collection protocols (Lodge 1998) did not contain a specified process for the sharing of data across sites. To remedy this, and to ensure that data could be 'safely' shared between sites and within themes, a data sharing and publication protocol was developed by the researchers in April 1999. This document was not legally binding and it relied on peer pressure and the goodwill of the cooperating scientists. It specified the terms associated with data sharing, and established a publication committee (chaired by the SGS Program coordinator) to review all publications and ensure appropriate data use and acknowledgment.

This protocol was considered to have a high potential since it overcame a perceived barrier to data sharing, but because of the 'risk' thought to be associated with data sharing, it required more negotiation with the sites than the data measurement protocols. Processes associated with data sharing and across-site analysis exposed some inherent inter-agency conflicts and personality difficulties:

> 'Data sharing issues have left a sour taste — a 'team player' test would be a good idea!'
>
> 'Data sharing worked OK, the main problem was that some sites had not got their data in order.'
>
> 'There are few other examples where data has been so freely exchanged prior to publication.'
>
> 'Publication seemed to work OK, but not data sharing. There were always great reservations about this from some, which continue to this day.'

A common database structure for each site allowed for data to be analysed by the themes. While the protocol provided some rigour and protection for sharing data, even with a high level of trust among the SGS National Experiment researchers, there was some underlying discomfort that was not entirely overcome, even in the harvest year. Nevertheless, by the end of the harvest year, complete access was given to all site databases for all SGS National Experiment researchers.

Producer involvement (*potential = 7.7*; *achievement = 69% of potential*)

Producers were involved at all levels in SGS (Mason *et al.* 2003*a*). Although many of the sites in the SGS National

Experiment were established before the Regional Producer Network (RPN) and regional committees (Simpson *et al.* 2003) were functioning, sites were planned with producer input. In addition, the major program funder (Meat & Livestock Australia, MLA) insisted that sites gain approval from a producer-dominated review team (a technology transfer advisory group) before commencing their experiments. Each site was reviewed by a group comprising local producers, a producer from the program steering group (Mason *et al.* 2003*a*), a scientist from another SGS National Experiment site and some input from SGS management. At some sites, this process reinforced existing plans, while at others, major changes were made based on the group's recommendations.

Producer input was generally seen as having considerable potential to improve the SGS National Experiment, but there was a very wide spread of opinion as to how well that potential was realised (Fig. 3). While researchers valued producers' input into general research priorities, a common concern was that producers may unduly influence experimental designs away from those that were focused on developing national principles into those that only investigated local issues. Most of the suggestions for improvement (Table 5) regarding producer involvement were positive, seeking increased and/or earlier involvement from producers.

> 'I think if research focuses solely on producer perspectives we may fail to gain understanding of the underlying principles.'

> 'Real producer involvement with researchers was perhaps the greatest innovation of SGS — especially as it was budgeted for BIG time.'

> 'Some sites minimal impact, other sites very large.'

Producer interaction with researchers was a key feature of the SGS Program (Andrew 2003; Nicholson *et al.* 2003; Price 2003; Mason *et al.* 2003*b*; Simpson *et al.* 2003). Producer input into the planning and operation of the SGS National Experiment varied between sites, but in the SGS National Experiment it was recognised that there was considerable potential benefit from more producer involvement early in the experimental programs (Table 5). Increased credibility for the research, leading to improved uptake of the results, was seen as one of the main advantages for producer involvement. The processes of workshops, producer forums, farm walks and field days, harvest year harvest teams (which comprised producers and researchers) and having national site research teams maintain close association with producer groups (both within and outside the RPN), all assisted interpreting and delivering research findings. Thus, SGS ensured that the research outcomes were relevant and clearly focused on producer adoption to achieve the program goal (Mason *et al.* 2003*a*). Hence, many of the research outcomes of the SGS National Experiment were, by necessity, required to be practical management options that producers could readily test and adopt on their own properties or in regional demonstration sites.

Price (2002) observed that the interaction among producers, researchers, consultants and managers associated with the program, and facilitated by SGS coordinators, generated over time a form of cultural capital unique to the SGS Program that enabled participants to relate to (and judge) one another not by their professional background, but by their commitment to SGS. This social phenomenon played a critical part in contextualising the different elements of the SGS Program, including the national experiment, among its different participants.

Pre-experimental modelling (*potential = 7.3*; *achievement = 67% of potential*)

A range of treatments were modelled for their likely potential impact on the water balance before the SGS National Experiment began (Bond *et al.* 1997; Simpson *et al.* 1998). Simulations were undertaken for 3 sites (Albany, Vasey and Tamworth). These concluded that, compared with woodlots, grazing management might only have a small impact on the water balance through water usage. In response to this, the focus on trees was increased, with the inclusion of plantation forestry at Albany (Sanford *et al.* 2003*a*) and the monitoring of water use of spaced trees at Vasey, north-east Victoria and Wagga Wagga.

Pre-experimental modelling was thought to have only a moderate potential impact, and average delivery (67% of potential). This may reflect the narrow range of modelling undertaken which concentrated mainly on the water balance. Nevertheless, a positive outcome of the exercise was that it crystallised the concept of developing the SGS Pasture Model.

> 'Great idea but I felt the tools were not really appropriate — hence the need to develop a customised model.'

> 'I sensed an anti-modelling attitude until the pre-experimental modelling was undertaken.'

> 'On reading the results of this modelling, and comparing with national experiment outcomes, I find the modellers did a good job under difficult conditions.'

Pre-experimental modelling was a substantial attempt to 'preview' the likely impacts of the experimental treatments in the SGS National Experiment, at least for the water balance. Some changes were made to the design of the SGS National Experiment, but overall the modelling results were not given the credibility they deserved by some of the sites. Interestingly, the general conclusions from the pre-experimental modelling (Bond *et al.* 1997) and the water theme paper (White *et al.* 2003) were very similar. However, the value of the SGS National Experiment was to provide an improved understanding of the dynamics of water in grazed pasture systems (White *et al.* 2003). Pre-experimental modelling should become a feature of future R&D programs, even if only a modest modelling capability exists.

Hunches (*potential = 7.1*; *achievement = 85% of potential*)

The first combined forum of SGS National Experiment researchers and the RPN was held in Armidale in March 2000. Producers were very keen for the researchers to present their results, but the researchers were generally reluctant because of the limited time for data collection (since spring 1997 at the earliest), and little or no statistical analysis of the data. A compromise was that sites would present their 'hunches' (tentative conclusions based on summaries and trends in the data derived using the database tools and some modelling, but not informed by rigorous statistical analysis and interpretation).

In response to the survey question about ways to improve the SGS National Experiment (Table 5), hunches were the only process that did not receive any suggestions for improvement.

> 'There is a question of liability if a producer uses a hunch that turns out to be incorrect!'

> 'My reservation is that 'hunches' can easily become 'facts', despite later analysis disproving them.'

> 'This was achieved, but it was not a very good idea.'

> 'Great idea, but challenging for scientists.'

Hunches were well received by the producers, but many researchers were uncomfortable with the process. Hunches are within the producers' comfort zone since producers routinely use their own or their peers' 'untested' findings in their decision-making. In contrast, for researchers, hunches were outside their comfort zones since they are trained to require more rigorous proof. Overwhelmingly, however, hunches proved to be substantially in agreement with the final SGS National Experiment findings with only 2 of the 50 hunches being refuted by the subsequent detailed analysis and 78% being fully supported. The remaining hunches (18%) were either not tested, or were inconclusive. These findings confirmed a commonly expressed sentiment of producers that hunches may not be any different from published results (Anon. 2002*a*). However, in analysing these outcomes it should be remembered that most hunches were conservative and, in making them, researchers had the benefit of prior research and knowledge. The key message from the SGS National Experiment experience is that hunches might provide a very useful device for fast-tracking the communication of research findings to leading producers, despite the unease of some scientists.

Aggregation of experiments (*potential = 6.2*; *achievement = 94% of potential*)

The SGS National Experiment became a 'national experiment' by integrating a series of different experiments through collaboration *via* the processes discussed above, rather than by adopting a common experimental design [see Andrew and Lodge (2003) for details], as was initially envisaged (Michalk and Saul 1995). This process involved 2 concepts: the idea of an aggregate experiment and the use of common treatments.

Of all the processes used in the SGS National Experiment, the aggregation of experiments was rated as having the lowest potential (6.2), with a 'near bimodal' response (Fig. 3). The rating for actual impact was the highest (94% of the potential) indicating that SGS probably did as well as it could have with this innovation. There were many suggestions for improving the design of the SGS National Experiment (Table 5) with the inclusion of a common treatment across all sites being the most frequent.

> 'I rated its actual > potential because of themes and the model.'

> 'Better for relevance of experiments for regions, but difficult for across-site comparison.'

> 'Could have had a common treatment — which would have assisted theme analyses.'

The 'experiments' that made up the SGS National Experiment ranged from fully replicated, plot-based experiments, to unreplicated catchments. The use of protocols, minimum datasets and modelling reduced the difficulties associated with having different experimental designs at different sites and, in particular, modelling helped to overcome the effects of confounding among sites, as envisaged at the outset of the SGS National Experiment. As previously noted, social processes such as participation in interdisciplinary forums, across-site and across-organisation team formation, and participation in guiding the directions of the SGS National Experiment also played a crucial role, alongside the shared application of various methodological tools, in galvanising the SGS National Experiment into a tangible social entity (Price 2003).

General discussion

SGS National Experiment findings — further work

The amount of material published from the SGS National Experiment is a substantial accomplishment due to the quantity, innovative approach to analysis, and speed of publication. Despite this, there is more that could be done to extract full value from the investment in the SGS National Experiment. The large, quality-assured, SGS National Experiment database, arguably the most extensive of its kind, contains more information than reported to date. While some key issues remain unexplored, there are also some opportunities for further analyses and modelling to extend the range of conclusions from the dataset collected. Some of these were recognised too late in the harvest year to be accommodated in the theme analyses; these included studying more closely the dynamics of evapotranspiration, runoff and deep drainage from pastures, by comparing empirical with modelled data, including using different models and time increments; thoroughly analysing the water use of trees relative to pastures by including the data from Vasey and Wagga Wagga sites and modelled analyses; further developing and testing the nutrient cycling components of the SGS Pasture Model by incorporating the forage mineral nutrient data and soil profile nutrient data that were collected from all SGS sites; comparing a range of techniques used within the SGS National Experiment to estimate herbage mass accumulation rate; and exploring the theme questions using other models in conjunction with the SGS Pasture Model. In addition, there are datasets that have not yet been reported, including the effect of treatment on wool production, and the dynamics of soil invertebrates in grazed ecosystems.

The framework of innovative R&D processes — a new research benchmark?

The SGS R&D processes collectively represented a new benchmark for R&D planning and management, and other research programs have adopted some of these innovations. High potential impact scores for almost all the R&D processes indicated that SGS researchers will want to adopt many of these processes in their future research activities and, by this means alone, the SGS National Experiment will change the wider R&D landscape.

It was to be expected that the actual impact of each the 13 processes was less than the potential. The SGS National Experiment was managed in a participative, action learning manner (with 6-monthly researcher meetings, where researchers earnestly evaluated progress and pondered new directions) with both management and researchers feeling their way as each increasingly moved into the unfamiliar territory created by concurrently adopting a whole set of innovations.

Implementing these innovations caused some difficulties and conflicts within the SGS National Experiment research community, particularly since they resulted in the SGS National Experiment evolving into a very different R&D model from that to which the researchers were initially committed (Price 2003). As the survey results showed, it took time for researchers to embrace these changes and become more familiar and comfortable with using these innovations as routine research and data exploration tools. This initially occurred with the database and then, more latterly, with the SGS Pasture Model. Compounding this effect was the use of themes, which were not part of the original planning. However, while some researchers cited a lack of funding (see below and Table 5), the real limitation to rapid adoption was the mental shift required to embrace a new way of doing things. The concept of sites being ‘data generators’ to support the themes (i.e. sites being a means to the end, not an end in themselves) was not internalised by many of the researchers. The SGS National Experiment reviewers' conclusion that ‘… there is much to be done if this [Themes] approach is to realise its potential’ (Johnson *et al*. 2001) proved to be very accurate.

Future programs will be able to benefit from the experiences of the researchers and the management of the SGS National Experiment, and incorporate the learnings reported in this paper. The high scores given to the potential for most of the innovations in the SGS National Experiment, and the lower scores for effectiveness of implementation, suggests that if all the R&D processes achieve their potential in future programs, the outcomes will be even richer.

A new R&D benchmark also has implications for research funders. Compared with more traditional approaches it required a higher level of coordination, pro-action and commitment by funders, research agencies (in providing in-kind contribution through expert staff), and the R&D program coordinators. An investment from MLA of about $A200 000 (or 10% of the cash budget) per year was required to fund the various activities needed to enable the SGS National Experiment to flourish (e.g. coordination, theme coordinator and part of the SGS coordinator; annual researcher and research executive meetings, database development and support, and themes), more than MLA itself invested in any single site. MLA considers that it received an excellent return on this investment.

Leadership and influence

The findings of the leadership survey were consistent with field observations (Price 2002, 2003) that the attribution of leadership within the SGS National Experiment was not primarily associated with formal hierarchical positions of authority. Rather, it emerged from the actions of particular individuals and the way these actions were perceived, and attributed legitimacy, by others. The conclusion is highly consistent with the findings of Oxley (1978), supporting his differentiation between the notions of leaders and commanders (i.e. the notion of leadership is in some sense a social construction).

The strong emphasis placed by respondents on traits based around innovation (94%), achievement (outcomes, 88%), motivation (relationships, 63%), experience (63%) and process (56%) resonates with the concept of transformational leadership (Chemers 1997; Hollander 1958). More specifically, respondents' nominees tended to be those who made things happen, supporting the distinction that transformation leadership is about what leaders do to get the team to participate and move in a new direction rather than what their inherent traits might be (Maxwell 1998).

The survey confirmed findings of previous studies on leadership. Interestingly, most traits identified by respondents in the SGS National Experiment survey were similar to those identified in typical leadership surveys of non-scientific institutions, save for 1 prominent omission, ‘honesty’. In undertaking and reviewing a wide range of leadership surveys on US organisations, Kouzes and Posner (1993) found that in nearly every survey, honesty was selected more often than any other leadership trait. That characteristics relating to honesty and ethics should be omitted by all respondents in the SGS survey was somewhat bemusing given the prominence scientific integrity enjoyed in the everyday performance of SGS research. Alternative explanations can be made to explain the absence of 'honesty' as a trait. First, for most, the concept of honesty is a given and is absorbed into other traits. Second, the various rituals of science are intended to ensure that honesty prevails, and hence this responsibility is lifted somewhat from the shoulders of leaders. Third, for some, the nature of the SGS Program called for different emphases of traits in its leadership.

Were the SGS National Experiment goals and objectives achieved and the funders' expectations met?

Andrew and Lodge (2003) presented the expectations of SGS funders about the anticipated achievements of the SGS National Experiment. While it is not possible to directly compare these with actual achievements since the SGS National Experiment evolved into a different program to that which was originally envisaged, the SGS National Experiment did achieve all of its goals and objectives (Table 6). As a result of the SGS National Experiment we have a much better understanding of which grazing practices are sustainable [expectation 1 from Andrew and Lodge (2003), Table 2] and the biophysical processes that underpin them (2), particularly the role of management tactics on the dynamics of water movement (3) including the role of trees (5). We understand better the trade-offs between production and sustainability including on- and off-site impacts (4). The SGS National Experiment made some progress towards developing tools for producers to benchmark their production and sustainability performance (10). Overall, the

Table 6. Achievement of SGS National Experiment goals and objectives

Goals and objectives	Evidence of achievement
Overarching goals	
• To fill the gaps in knowledge relating to the major profitability and sustainability issues in high rainfall zone grazing systems in southern Australia	This paper, and the site and theme papers in this Special Issue
• To create an enriching environment for researchers and producers alike	The triple bottom line assessment by SGS National Experiment researchers gave relatively high scores for professional development (7.9/10) and personal satisfaction (7.2/10) (Mason *et al*. 2003*b*)
Specific goals	
• Quantify the relationships between management options, and production and sustainability outcomes across a range of grazing systems	Theme papers in this Special Issue
• Develop grazing systems that were more sustainable and at least 10% more profitable than current practice	Site papers in this Special Issue, and Barlow *et al*. (2003)
• Facilitate rapid delivery of the research results to producers through the RPN	*via* hunches, articles in 'Prograzier', Tips & Tools, various field days, SGS Technical Manual, etc. Indeed, the SGS National Experiment had a broad impact — Allan *et al*. (2003) reported that the rates of awareness and experiment site. Similarly, attribution to SGS, describing how SGS had helped producers manage water, nutrients, participation and the associated practice change were not related to whether a region contained a SGS National Experiment site. Similarly, attribution to SGS, describing how SGS had helped producers manage water, nutrients, animals, pastures or information exchange, was not different in those regions with a SGS National Experiment site.
• Develop a more effective model for conducting large scale, industry-focused research.	This paper
Specific objectives	
• Demonstrate that grazing management can increase pasture productivity and sustainability by improving perennial grass composition and increasing persistence	Pasture theme paper (Sanford *et al*. 2003*b*)
• Determine the profitability of grazing strategies within sustainable parameters	Site papers in this Special Issue, Barlow *et al*. (2003)
• Determine the management needed to provide critical ground cover and or biomass to prevent erosion and promote soil health	Pasture theme paper (Sanford *et al*. 2003*b*), Lodge *et al*. (2003*a*, 2003*b*), Packer *et al*. (2003).
• Develop strategies that maximise water use and minimise salinity and acidity	Water theme paper (White *et al*. 2003).
• Identify strategies that optimise animal production and reduce nutrient losses	Animal theme paper (Graham *et al*. 2003); Nutrient theme paper (McCaskill *et al*. 2003)
• Determine the impact of grazing systems and management intensifications on biodiversity	Biodiversity theme paper (Kemp *et al*. 2003)

SGS National Experiment R&D processes were viewed collectively as a successful R&D model (12) in that it created a network of researchers interested in sustainability and production issues (13); indeed, it provides the model needed to deal with complex interactions in ecosystems that Cullen (2002) identified as being essential if we are to move towards sustainability.

The SGS National Experiment did not make substantial progress with those achievements that required comprehensive use of the model and other tools to extrapolate the findings in space and time (6) so they could be localised for individual producers' circumstances (8, 9), and also integrated with those from the producer-driven regional sites (7, 11). We consider that better adoption of the innovative R&D processes would have enabled these to be achieved within the life of SGS.

As stated earlier, the SGS National Experiment design was conservative, focused on exploring the sustainability and profitability of mainstream grazing enterprises. It did not include radical treatments that some funders and researchers had hoped for. Ideas for radical research were canvassed early in the life of the SGS National Experiment, but were not proceeded with for budget, logistical and practical/producer reasons. Implementing the 'conservative' SGS National Experiment design provided more than enough challenges, the lessons from which form a good basis for more radical designs in the future.

Conclusions

The SGS National Experiment was a major step forward in the implementation of large-scale agricultural R&D focused on delivering practical results to livestock producers, quickly. It largely achieved its formal goals, objectives and expectations, and created a supportive social environment (Price 2003). By establishing a new benchmark for research programs, the SGS National Experiment has changed the landscape of large-scale farming systems R&D, and has challenged other programs to further extend the boundaries. As judged by peer and independent review, the processes implemented in the SGS National Experiment were a collective success and provided the type of organisational structure that Cullen (2002) described as being essential for solving environmental problems by delivering good science and practical application at the landscape, rather than plot, scale. How well the more immediate benefits of these successes of the SGS National Experiment were captured and translated into producer adoption of more productive and sustainable grazing practices is discussed by Allan *et al.* (2003), Andrew (2003), Mason *et al.* (2003*b*), Nicholson *et al.* (2003) and Simpson *et al.* (2003).

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References

Allan CJ, Mason WK, Reeve IJ, Hooper S (2003) Evaluation of the impact of SGS on livestock producers and their practices. *Australian Journal of Experimental Agriculture* **43**, 1031–1040.

Anon. (2000) 'Australian and New Zealand guidelines for fresh and marine water quality. Aquatic ecosystems — rationale and background information.' Paper No. 4, Vol. 2 (Chapter 8) (Australian Water Association: Sydney, Australia). Available at http://www.ea.gov.au/water/quality/nwqms (verified 28 May 2003)

Anon. (2002*a*) 'SGS (Sustainable Grazing Systems) final report. A triple bottom line report.' (Meat and Livestock Australia: Sydney)

Anon. (2002*b*) 'Evaluation of SGS harvest year.' Prepared by Hassall & Associates, December 2002. (Meat and Livestock Australia: Sydney). http://www.mla.com.au

Andrew J (2003) Key features of the regional producer network for enabling social learning. *Australian Journal of Experimental Agriculture* **43**, 1015–1029.

Andrew MH, Lodge GM (2003) The Sustainable Grazing Systems National Experiment. 1. Introduction and methods. *Australian Journal of Experimental Agriculture* **43**, 695–709.

Barlow R, Ellis NJS, Mason WK (2003) A practical framework to evaluate and report combined natural resource and production outcomes of agricultural research to livestock producers. *Australian Journal of Experimental Agriculture* **43**, 745–754.

Bond WJ, Cresswell HP, Simpson RJ, Paydar Z, Clark SG, Moore AD, Alcock DJ, Donnelly JR, Freer M, Keating BA, Huth NI, Snow VO (1997) 'Pre-experimentation water balance investigation for the MRC Sustainable Grazing Systems Key Program.' CSIRO Land and Water Consultancy Report 97–31, CSIRO, Canberra.

Carberry PS, Hochman Z, McCown RL, Dalgleish NP, Foale MA, Poulton PL, Hargreaves JNG, Hargreaves DMG, Cawthray S, Hillcoat N, Robertson MJ (2002) The FARMSCAPE approach to decision support: farmers', advisers', researchers' monitoring, simulation, communication and performance evaluation. *Agricultural Systems* **74**, 141–177.

Chapman DF, McCaskill MR, Quigley PE, Thompson AN, Graham JF, Borg D, Lamb J, Kearney G, Saul GR, Clark SG (2003) Effects of grazing method and fertiliser inputs on the productivity and sustainability of phalaris-based pastures in western Victoria. *Australian Journal of Experimental Agriculture* **43**, 785–798.

Chemers MM (1997) 'An integrative theory of leadership.' (Lawrence Erlbaum Associates: New Jersey)

Cullen P (2002) Environmental aspects of sustainability. In 'Transition to sustainability'. Australian Academy of Science Symposium Proceedings. Available at http://www.science.org.au/sats2002/cullen.htm (verified 28 May 2003)

Franko U, Schramm G, Rodionova V, Korschens M, Smith P, Coleman K, Romanenkov V, Shevtsova L (2002) EuroSOMNET — a database for long-term experiments on soil organic matter in Europe. *Computers and Electronics in Agriculture* **33**, 233–239.

Garden DL, Ellis NJS, Rab MA, Langford CM, Johnston WH, Shields C, Murphy T, Holmberg M, Dassanayake KB, Harden S (2003) Fertiliser and grazing effects on production and botanical composition of native grasslands in south-east Australia. *Australian Journal of Experimental Agriculture* **43**, 843–859.

Graham JF, Cullen BR, Lodge GM, Andrew MH, Christy BP, Holst PJ, Wang X, Murphy SR, Thompson AN (2003) SGS Animal Production Theme: effect of grazing system on animal productivity and sustainability across southern Australia. *Australian Journal of Experimental Agriculture* **43**, 977–991.

Hunt LA, White JW, Hoogenboom G (2001) Agronomic data: advances in documentation and protocols for exchange and use. *Agricultural Systems* **70**, 477–492.

Hollander EP (1958) Conformity, status and idiosyncrasy credit. *Psychological Review* **65**, 117–127.

Johnson IR, Lodge GM, White RE (2003) The Sustainable Grazing Systems Pasture Model: description, philosophy and application to the SGS National Experiment. *Australian Journal of Experimental Agriculture* **43**, 711–728.

Johnson T, Barlow R, Freebairn D (2001) 'Review of the SGS National Experiment. Final report to MLA.' (Meat & Livestock Australia: Sydney)

Johnston WH, Garden DL, Rančić A, Koen TB, Dassanayake KB, Langford CM, Ellis NJS, Rab MA, Tuteja NK, Mitchell M, Wadsworth J, Dight D, Holbrook K, LeLievre R, McGeoch SM (2003) The impact of pasture development and grazing on water-yielding catchments in the Murray–Darling Basin in south-eastern Australia. *Australian Journal of Experimental Agriculture* **43**, 817–841.

Kemp DR, King WMcG, Gilmour AR, Lodge GM, Murphy SR, Quigley PE, Sanford P, Andrew MH (2003) SGS Biodiversity Theme: impact of plant biodiversity on the productivity and stability of grazing systems across southern Australia. *Australian Journal of Experimental Agriculture* **43**, 961–975.

Kemp DR, Michalk DL, Virgona JM (2000) Towards more sustainable pastures: lessons learnt. *Australian Journal of Experimental Agriculture* **40**, 343–356.

Kouzes JM, Posner BZ (1993) 'Credibility: how leaders gain and lose it, why people demand it.' (Jossey-Bass Publishers: San Francisco)

Lodge GM (Ed.) (1998) 'Themes and experimental protocols for sustainable grazing systems.' LWRRDC Occasional Paper No. 13/98. Land & Water Resources Research & Development Corporation, Canberra.

Lodge GM, Garden DL (2000) Grazing management studies in the Temperate Pasture Sustainability Key Program: site descriptions, treatments and data collection. *Australian Journal of Experimental Agriculture* **40**, 133–141.

Lodge GM, Murphy SR, Harden S (2003*a*) 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**, 875–890.

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. 2. A mixed native pasture, Manilla, North West Slopes, New South Wales. *Australian Journal of Experimental Agriculture* **43**, 891–905.

Lodge GM, Murphy SR, Harden S (2003*c*) 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**, 539–552.

McCaskill MR, Ridley AM, Okom A, White RE, Andrew MH, Michalk DL, Melland A, Johnston WH, Murphy SR (2003) SGS Nutrient Theme: environmental assessment of nutrient application to extensive pastures in the high rainfall zone of southern Australia. *Australian Journal of Experimental Agriculture* **43**, 927–944.

McCown RL (1982) The climatic potential for beef cattle production in tropical Australia. Part IV. Variation in seasonal and annual productivity. *Agricultural Systems* **8**, 3–15.

McDowall MM, Hall DJM, Johnson DA, Bowyer J, Spicer P (2003) Kikuyu and annual pasture: a characterisation of a productive and sustainable beef production system on the south coast of Western Australia. *Australian Journal of Experimental Agriculture* **43**, 769–783.

Mason WK, Lamb K, Russell B (2003*a*) The Sustainable Grazing Systems Program: new solutions for livestock producers. *Australian Journal of Experimental Agriculture* **43**, 663–672.

Mason WK, Lodge GM, Allan CJ, Andrew MH, Johnson T, Russell B, Simpson IH (2003) An appraisal of Sustainable Grazing Systems: the program, the triple bottom line impacts and the sustainability of grazing systems. *Australian Journal of Experimental Agriculture* **43**, 1061–1082.

Mason WK, Andrew MH (1998) Sustainable grazing systems (SGS) — developing a national experiment. In 'Proceedings of the 9th Australian agronomy conference'. Wagga Wagga. (Eds DL Michalk, JE Pratley) pp. 314–317. (The Australian Agronomy Society: Melbourne)

Maxwell JC (1993) 'Developing the leader within you.' (Thomas Nelson Publishers: Nashville, USA)

Maxwell JC (1998) 'The 21 irrefutable laws of leadership.' (Thomas Nelson Publishers: Nashville, USA)

Michalk D, Saul G (1995) 'Temperate pasture sustainability key program phase 2 planning.' Consultancy Report 'Design options for measuring livestock response in Phase 2.' (Meat & Livestock Australia: Sydney)

Michalk DL, Dowling PM, Kemp DR, King WMcG, Packer IJ, Holst PJ, Jones RE, Priest SM, Millar GD, Brisbane S, Stanley DF (2003) Sustainable grazing systems for the Central Tablelands, New South Wales. *Australian Journal of Experimental Agriculture* **43**, 861–874.

Nicholson C, Barr N, Kentish A, Dowling PM, McCormick LH, Palmer M, Simpson IH, Simpson K, Walsh J (2003) A research–extension model for encouraging the adoption of productive and sustainable practice in high rainfall grazing areas. *Australian Journal of Experimental Agriculture* **43**, 685–694.

Oxley H (1978) 'Mateship in local organisation (2nd edn).' (University of Queensland Press: Brisbane)

Packer WI, Michalk DL, Brisbane S, Dowling PM, Millar DG, King WMcG, Kemp DR, Priest SM (2003) Reducing deep drainage through controlled runoff management in high recharge tablelands landscape. In 'Solutions for a better environment'. In 'Proceedings of the 11th Australian Agronomy Conference' Geelong, Victoria. Published on CDROM ISBN 0–9750313–0-9. Available at http://www.regional.org.au/local/sites/regional/pub/au/asa/2003/c/8/michalk.htm

Price RJ (2003) Social spaces and boundary work in the Sustainable Grazing Systems Program. *Australian Journal of Experimental Agriculture* **43**, 1041–1059.

Price RJ (2002) 'Identifying social spaces and boundaries in complex research programs: a study of the SGS Program.' PhD Thesis, Charles Sturt University, Wagga Wagga, Australia.

Ridley AM, White RE, Simpson RJ, Callinan L (1997) Water use and drainage under phalaris, cocksfoot and annual ryegrass pastures. *Australian Journal of Agricultural Research* **48**, 1011–1023.

Ridley AM, Christy BP, White RE, McLean T, Green R (2003) North-east Victoria SGS National Experiment site: water and nutrient losses from grazing systems on contrasting soil types and levels of input. *Australian Journal of Experimental Agriculture* **43**, 799–815.

Sanford P, Wang X, Greathead KD, Gladman JH, Speijers J (2003*a*) Impact of Tasmanian blue gum belts and kikuyu-based pasture on sheep production and groundwater recharge in south-western Western Australia. *Australian Journal of Experimental Agriculture* **43**, 755–767.

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*b*) SGS Pasture Theme: effect of climate, soil factors and management on pasture production and stability in the high rainfall zone of southern Australia. *Australian Journal of Experimental Agriculture* **43**, 945–959.

Sanford P, Graham JF, Lodge GM, White RE, Kemp DR (2003*c*) Constraints to productive and sustainable grazing systems in temperate southern Australian grasslands. In 'Proceedings of the 7th International Rangelands Congress'. Durban, South Africa, July–August 2003. (Eds N Allsopp, AR Palmer, SJ Milton, GIH Kerley, CR Hurt, CJ Brown) pp. 113–115. (Document Transformation Technologies: Irene, South Africa)

Scott JM, Hutchinson KJ, King KL, Chen W, McLeod M, Blair GJ, White A, Wilkinson D, Lefroy RDB, Cresswell H, Daniel H, Harris C, MacLeod DA, Blair N, Chamberlain G (2000*a*) Quantifying the sustainability of grazed pastures on the Northern Tablelands of NSW. *Australian Journal of Experimental Agriculture* **40**, 257–265.

Scott JF, Lodge GM, McCormick LH (2000*b*) Economics of increasing the persistence of sown pastures: costs, stocking rate and cash flow. *Australian Journal of Experimental Agriculture* **40**, 313–324.

Scott JM, Lord CJ (2003) SGS Database: use of relational databases to enhance data management for multi-site experiments. *Australian Journal of Experimental Agriculture* **43**, 729–743.

Simpson RJ, Bond WJ, Cresswell HP, Paydar Z, Clark SG, Moore AD, Alcock DJ, Donnelly JR, Freer M, Keating BA, Huth NI, Snow VO (1998) A strategic assessment of sustainability of grazed pasture systems in terms of their water balance. In 'Proceedings of the 9th Australian agronomy conference'. Wagga Wagga. (Eds DL Michalk, JE Pratley) pp. 239–242. (The Australian Agronomy Society Inc.: Melbourne)

Simpson IH, Kay G, Mason WK (2003) The SGS Regional Producer Network: a successful application of interactive participation. *Australian Journal of Experimental Agriculture* **43**, 673–684.

Tilman D (1982) 'Resource competition and community structure.' (Princeton University Press: Princeton, USA)

van Evert FK, Spaans JA, Krieger SD, Carlis JV, Baker JM (1999*a*) Experiment design and data management. A database for agroecological research data: 1. Data Model. *Agronomy Journal* **91**, 54–62.

van Evert FK, Spaans JA, Krieger SD, Carlis JV, Baker JM (1999*b*) Experiment design and data management. A database for agroecological research data: 2. A relational implementation. *Agronomy Journal* **91**, 62–71.

White RE, Christy BP, Ridley AM, Okom AE, Murphy SR, Johnston WH, Michalk DL, Sanford P, McCaskill MR, Johnson IR, Garden DL, Hall DJM, Andrew MH (2003) SGS Water Theme: influence of soil, pasture type and management on water use in grazing systems across the high rainfall zone of southern Australia. *Australian Journal of Experimental Agriculture* **43**, 907–926.

White RE, Helyar, KR, Ridley AM, Chen D, Heng LK, Evans J, Fisher R, Hirth JR, Mele PM, Morrison GR, Cresswell HP, Paydar Z, Dunin FX, Dove H, Simpson RJ (2000) Soil factors affecting the sustainability and productivity of perennial and annual pastures in the high rainfall zone of south-eastern Australia. *Australian Journal of Experimental Agriculture* **40**, 267–283.

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