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OBJECTIVE 'SAFE' GRAZING CAPACITIES FOR SOUTH-WEST QUEENSLAND AUSTRALIA: MODEL APPLICATION AND EVALUATION

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Abstract

This paper describes the employment of two experienced graziers as consultants to apply and evaluate a model for calculating 'safe' long-term grazing capacities of individual properties. The model was based on ecological principles and entailed estimates of average annual forage grown (kg/ha) on the different land systems on each property and the calculation of the number of livestock (dry sheep equivalents, DSE) required to 'safely' utilise this forage.

The grazier consultants applied and evaluated the 'safe' grazing capacity model on 20 properties of their choosing. For evaluation, model results were compared with; (a) the Department of Lands rated carrying capacities for those properties and (b) the grazing capacity assessed independently by the owners of those properties. For the 20 properties, the average 'safe' grazing capacity calculated by the model (21.0 DSE/km^2) was 8% lighter than the average of the owner assessed capacities (22.7 DSE/km^2), which in turn was 37% lighter than the average of the pre-1989 Department of Lands rated carrying capacity (31.0 DSE/km^2). The grazing land management and administrative implications of these results and the role graziers played as consultants are discussed.

Introduction

The 32 million hectares (ha) of south-west Queensland experiences a semi-arid sub-tropical climate (<400 mm median annual rainfall) and supports an extensive grazing industry. The majority of the regions four million sheep and 600,000 cattle graze native unimproved pastures on 674 properties ranging in size from 5,000 ha to 300,000 ha. The vegetation is a mixture of timbered mulga (*Acacia aneura*) and treeless mitchell grass (*Astrebla* spp.) pastures. The mulga soils are predominantly sandy red earths, acidic in reaction (pH 5.5), low in nutrients (total nitrogen 0.044%, total phosphorus 0.025% and organic carbon 0.77%) and with a low water holding capacity (8.6% at -33 kPa) (Ahern and Mills 1990). Mitchell grass pastures are found on cracking clay soils of better fertility and water holding capacity. Ninety per cent of annual forage growth occurs over summer (Christie and Hughes 1983).

To assist those managing grazing lands in this environment, Johnston *et al.* (1996) described a model for objectively estimating 'safe' grazing capacities of individual properties in south-west Queensland. They indicated the model may offer graziers, land administrators and financiers a tool to (a) guide strategic decisions (20-30 year) regarding grazing capacities and (b) assist in an objective review of grazing capacities of individual properties in south-west Queensland. While tools for assessing grazing capacities and stocking rates have been described by Condon *et al.* (1969) (for western New South Wales, Australia), Christie and Hughes (1983) (south-west Queensland, Australia), Forge (1994) (Queensland, Australia), Scanlan *et al.* (1994) (North Queensland, Australia), Curry *et al.* (1994) (Murchison river catchment, Western Australia), Pringle *et al.* (1994) (north-eastern goldfields, Western Australia), Ogwang (1992) (Swaziland, Africa), de Leeuw and Tothill (1993) (Sub-Saharan Africa) and Holechek (1988) (United States rangelands), none have been applied and evaluated on individual properties in south-west Queensland.

This paper describes the application and evaluation of the model of Johnston *et al.* (1996) by two experienced south-west Queensland graziers on 20 properties across the region. The graziers were employed as consultants by the Queensland Department of Lands and were chosen for their knowledge of the region and their ability to relate to other graziers.

Materials and methods

The model

The method for estimating grazing capacities developed by Johnston *et al.* (1996) entailed the estimation of the average annual forage grown (kg/ha) on the different land systems on each property. This estimate was based on the product of an average annual rainfall use efficiency for each land system (Johnston unpublished) and the long-term average rainfall for the property. The estimate also accounted for the impact of tree and shrub cover on forage production. An estimate of the number of livestock required to utilise a 'safe' portion of the average annual forage grown was then calculated. Summing the livestock numbers for each land system on a property produced an estimate of the 'safe' long-term grazing capacity for that property.

The term 'safe' implies conservative levels of forage utilisation by domestic livestock and subsequent sustainable resource use. The derivation of these conservative levels of forage utilisation was conducted without quantification of the grazing pressure attributed to other herbivores such as kangaroos, goats and insects. The ability to manage populations of other herbivores and to estimate their contribution to total grazing pressure would result in different levels of 'safe' forage utilisation.

Roles of the grazier consultants

The Department of Lands appointed three experienced graziers as 'grazing capacity consultants' in February 1994. Their role was to evaluate the above model as a means to estimating 'safe' long-term grazing capacities on selected properties in the mulga lands of south-west Queensland. A consultant was chosen from each of three broad bio-geographical regions (eastern mulga lands (Booringa, Balonne and Warroo shires), central mulga lands (Paroo and Murweh shires - east of the Warrego river) and western mulga lands (Paroo, Bulloo and Quilpie shires - west of the Warrego river). There was a combined 160 years of grazing land management experience between the consultants and agency staff involved with this exercise.

The duties of the consultants were to:

- Undertake training in the concepts and techniques behind the model;
- Trial the model and techniques on the consultant's own property. This entailed; a detailed inspection of the property; refinement of the land system mapping where necessary; estimating tree and woody weed cover using step point methodology; and calculating a long-term grazing capacity for each land system and the property overall;
- Select receptive graziers in their regions willing to have their properties assessed;
- Arrange for relevant maps to be prepared prior to property inspections;
- Visit each property to discuss the model, refine the land system maps (if necessary), assess the condition of each land system and estimate a 'safe' long-term grazing capacity;
- Prepare a report for each property for the benefit of each landholder; and
- Prepare a public report for the Department of Lands summarising the findings from all properties.

Packaging the model and consultant training

A manual was compiled summarising the concepts and steps in the model for estimating 'safe' grazing capacities. Apart from the land system maps for each property, the manual provided the necessary formulae, data and working sheets to estimate a 'safe' grazing capacity for any property in south-west Queensland. The working sheets were designed to enable all the grazing capacity calculations to be performed either by hand or with a calculator (no 'black box'). Cadastral and land system maps overlain on satellite imagery for each property were supplied by the Department of Lands.

In March 1994, a three day training session (lead by the authors) was held to instruct the grazier consultants in the background and steps involved in estimating grazing capacities for individual properties. The session included sections on the ecological principles behind the model, techniques for sampling foliage projected cover of trees and shrubs using the step point methodology of Evans and Love (1957) and sighting tube of Buell and Cantlon (1950) and performing the calculations.

As a case study, the method was applied to the 5362 ha Queensland Department of Primary Industries' research station 'Croxdale' (26°27' South, 146°09' East). The land system mapping for 'Croxdale' was examined and representative locations within the various land systems sampled for tree and shrub cover using the method described by Johnston *et al.* (1996). The calculations to estimate a 'safe' long-term grazing capacity for 'Croxdale' were performed and discussed as a group.

Following the initial training, each of the consultants assessed their own properties as a team. This was to develop confidence in the approach while in familiar surroundings. Due to the unavailability of the land system mapping used in model development east of 147°, only two of the consultants were able to fully proceed with application of the model. The land system mapping of Mills and Lee (1990) ends at 147° East.

Following these assessments, the remaining two consultants approached an additional 18 commercial graziers who had been in the region >10 years, and sought to conduct property assessments to evaluate the model on their properties. They were selected to cover a range of country types and locations across south-west Queensland as shown in Fig. 1. The properties were considered 'reasonably well managed' with the grazing of sheep and cattle as the main enterprise. Confidentiality of individual property information was assured.

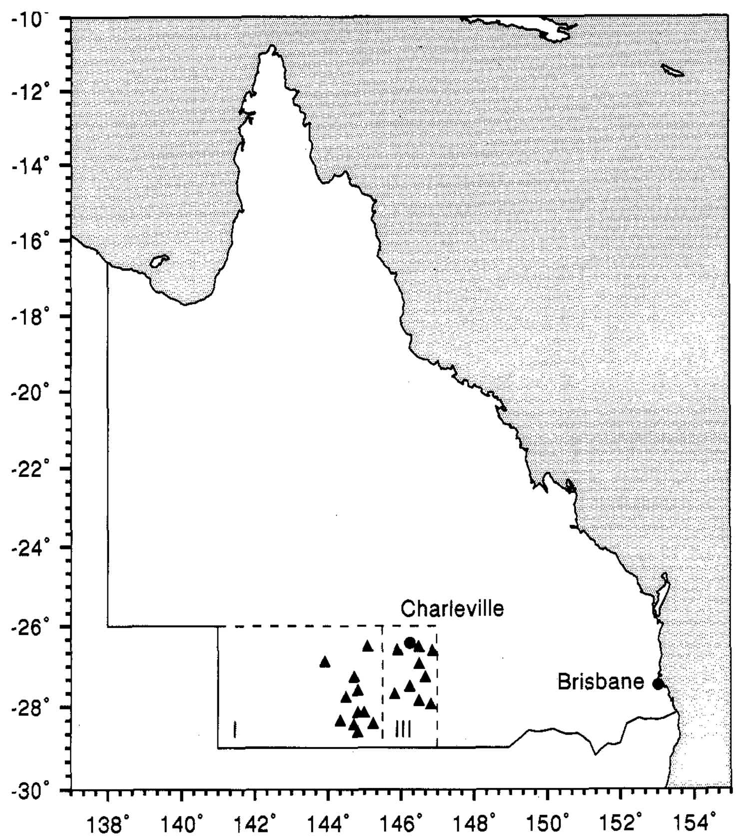

Fig. 1. Location of 20 grazing properties in south-west Queensland selected by two grazier consultants to apply and evaluate a model for calculating 'safe' long-term grazing capacities of individual properties. The land system map areas of (I) Dawson (1974) and (III) Mills and Lee (1990) are shown dotted.

Apart from estimates of tree and shrub cover, detailed surveys of the pasture condition on these properties have not been conducted. Had such data been available it still would not have been possible to quantitatively compare the condition of the properties with others in south-west Queensland due to the lack of regular regional scale monitoring in the district. The following results refer to the work of the two remaining consultants (Cooney (1995) and Crichton (1995)). To evaluate the model, results were compared with; (a) the Department of Lands rated carrying capacities for those properties and (b) the grazing capacity assessed independently by the owners of those properties from their own records and knowledge of their properties. Regression analysis and the simultaneous F-test of unit slope and zero intercept (Mayer and Butler 1993) were used to compare grazing capacities calculated by the model with those assessed by the owners.

Results

The learning process

No formal evaluation of the training session was conducted. The following are qualitative observations regarding the learning process and grazier perceptions of the model.

Each of the grazier consultants grasped the issues relating to grazing capacities in south-west Queensland and the need to review these values using an objective method. When initially presented with the basic ecological principles behind the model, it was difficult to determine the depth of understanding. However, in the field at 'Croxdale' the consultants rapidly developed an understanding of the principles and techniques for recognising different land systems and sampling tree and shrub cover. They became conversant with the terminology and began using it regularly when discussing the work.

During the property assessments a number of aspects in the model required refinement and are incorporated in the model described by Johnston *et al.* (1996). This included an examination of the relativities between rainfall use efficiencies across different land systems. This lead to the development of a relationship between rainfall use efficiencies and soils data for each land system (Johnston *et al.* 1996). A factor to accommodate the extra water available for forage growth on frequently flooded land systems was also developed. Through consensus it was determined that average annual rainfall was increased by 30% and 15% on land systems flooded once every two years and once every two to five years respectively. The questioning and identification of these aspects indicated that the consultants had developed a sound understanding of the components of the model.

In June 1995, the two consultants presented their findings for discussion. Refinements to the model based on issues they identified were discussed. A 'safe' long-term grazing capacity for each of the 20 properties was then calculated using the refined model described by Johnston *et al.* (1996) and the data collected by the grazier consultants. The grazier consultants then reported back to the participating graziers on the findings for each property. A report to the Queensland Department of Lands was also prepared by each consultant (Cooney 1995 and Crichton 1995).

Grazier observations regarding the model

Twenty grazing properties in south-west Queensland (average size 32,916 ha) were assessed during the period March 1994 to June 1995 (Fig. 1). Regarding the model Cooney (1995) and Crichton (1995) reported:

- 'More research should be conducted into all aspects of the methodology, particularly the rainfall use efficiencies and the effect of tree and shrub cover on pasture growth;

- The model should 'not be set in concrete' and should be reviewed and further refined at regular intervals to account for the findings of new research. These reviews would also cater for improving satellite technology and other techniques as they arise;
- Continuous upgrading of the land system mapping on a property by property basis would improve the accuracy of the 'safe' grazing capacity estimation. Eventually, every property should be done separately;
- Most landholders have a deep suspicion that this exercise is the first step towards controlled stocking and greater government control in how they run their properties. Security of tenure and property size of an adequate 'living area' were two issues identified as being closely linked with 'safe' grazing capacities;
- The presentation of grazing capacities should be re-thought. Rather than hectares per DSE the land's capacity should be expressed as 'units of production' (e.g. kg of wool or beef per hectare). Everything leaving the property would have a 'unit of production value' which can be related to the current components of the grazing capacity estimation (land system, rainfall, forage grown and tree and shrub cover);
- Various relevant bodies and particularly the grazing industry accept the model for estimating the grazing capacities in the mulga lands of south-west Queensland;
- Grazing capacities must be looked at in the full context of land care, and not simply how many animals the land resource can support; and
- The impact of less palatable forage species (e.g. wire grasses (*Aristida* spp.)) on the level of forage utilisation needs to be examined.'

Land systems and land condition

A total of 6583 km^2 was assessed covering 77 different land system combinations described by Dawson (1974) and Mills and Lee (1990) (Table 1). The average annual rainfall for the twenty properties was 357 mm. Sixty-one percent of the area assessed was either the soft mulga land zone (2065 km^2 or 31%) or the hard mulga land zone (1966 km^2 or 30%). The average foliage projected canopy cover (FPC) of trees on the twenty properties was 9.6% (range 0.0% to 30.6%) and the average FPC of woody weeds was 6.5 % (range 0.0% to 38.3%). The soft mulga land zone supported the highest density of trees (FPC of 13.6%) and the open downs the lowest (FPC of 0.0%). The sandplain land zone had the highest density of woody weeds (FPC of 21.6%) and the open downs the lowest (0.0%). The sandplain land zone also had the highest total woody vegetative cover (FPC of 28.1%) and the open downs the lowest (FPC of 0.0%).

Grazing capacity comparisons

For the 20 properties, the average 'safe' grazing capacity (21.0 DSE/km^2) calculated by the consultants using the refined model described by Johnston *et al.* (1996) was 8% lighter than the average of the grazing capacities assessed independently by the owners (22.7 DSE/km^2) (Table 2). The average of the owner assessed capacities (22.7 DSE/km^2) was 37% lighter than the average of the pre-1989 Department of Lands rated carrying capacity (31.0 DSE/km^2, Table 2).

Seventy-five per cent of the owner's assessed grazing capacities were within ±10% of the model's calculated grazing capacity (Table 2). There was a significant relationship (slope nsd 1.0 and intercept nsd 0.0 at $P<0.05$) between the model's calculated 'safe' grazing capacity and the owners assessed grazing capacity (Fig. 2) when two outliers were removed on recommendation of the consultants (a greater use of mulga leaf as a source of forage). The ratio of owner assessed grazing capacities to those of the model (average 1.08, range 1.39 to 0.95) was neither related to property nor flock size (Figs 3a and 3b). On six of the twenty properties, the owner assessed grazing capacity was more conservative than the model's 'safe' grazing capacity.

Table 1. Total area, average rainfall, average foliage projected cover (FPC%) of trees and shrubs and total cover for the 13 of the 15 land zones (Dawson (1974) and Mills and Lee (1990)) encountered in the assessment of 77 land systems on 20 grazing properties in south-west Queensland.

Land Zone	Area (ha)	Rainfall (mm)	Tree (FPC%)	Shrub (FPC%)	Total (FPC%)
Alluvial Plains Open (A)+	33340	327	3.5	1.2	4.7
Brigalow (B)*	0				
Channel Country (C)	718	303	5.0	0.0	5.0
Dunefields (D)	13614	338	5.3	15.6	20.0
Poplar Box Lands (E)	18528	434	10.8	4.6	14.9
Downs (F)	247	325	0.0	0.0	0.0
Gidgee Lands (G)	40546	328	8.4	4.8	12.8
Hard Mulga Lands (H)	196626	354	8.1	5.0	12.6
Claypans (L)	11542	376	5.2	1.4	6.5
Soft Mulga Lands (M)	206512	372	13.6	4.8	17.7
Spinifex Sandplains (N)	18204	423	9.3	17.6	25.3
Dissected Residuals (R)	37309	360	9.8	12.2	20.8
Mulga Sandplains (S)	39856	344	8.3	21.6	28.1
Wooded Downs (T) *	0				
Alluvial Plains Wooded (W)	41283	338	5.9	3.0	8.7
Mean	43888	308	6.2	6.1	11.8

+ Code letter for land zones used by Dawson (1974) and Mills and Lee (1990).
* Land zones not encountered on the properties assessed.

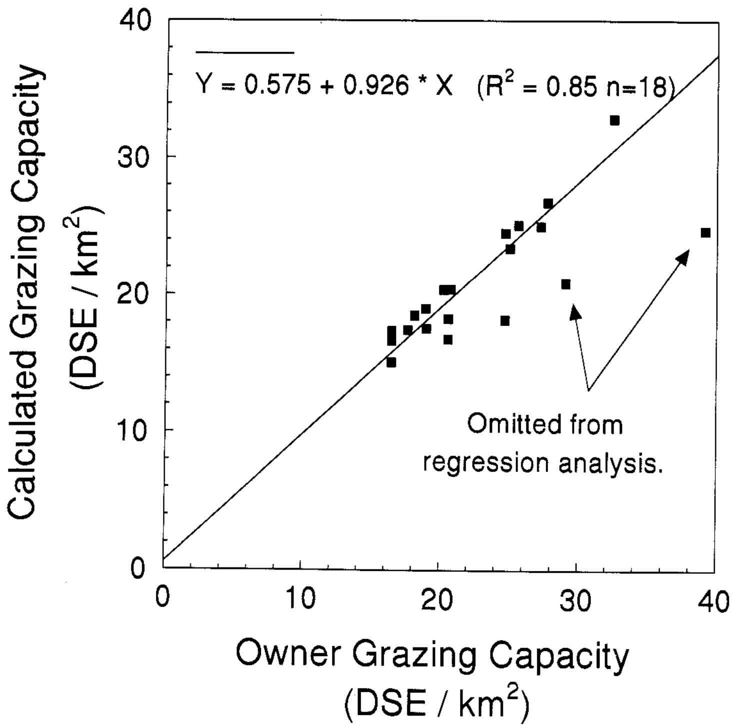

Fig. 2. Comparison between calculated 'safe' grazing capacities and owner assessed grazing capacities on 18 grazing properties in south-west Queensland selected by two grazier consultants applying and evaluating a model for estimating 'safe' long-term grazing capacities of individual properties (slope nsd 1.0, intercept nsd 0.0 $P < 0.05$).

Table 2. Owner assessed grazing capacities, calculated 'safe' grazing capacities (using the model of Johnston *et al.* 1996) and the pre-1989 Department of Lands (DOL) rated carrying capacities (P.R. Tannock, pers. comm.), and grazing capacity ratios for 20 properties in south-west Queensland assessed by grazier consultants.

Property	Owner (DSE/km^2)	Calculated (DSE/km^2)	DOL (DSE/km^2)	Owner: DOL	Owner: Calculated	DOL: Calculated
A	17.6	17.5	33.9	1.01	0.52	1.94
B	20.7	20.4	29.1	1.02	0.71	1.42
C	19.0	17.6	31.6	1.08	0.60	1.80
D	20.6	16.8	26.6	1.22	0.78	1.58
E	16.5	16.7	22.5	0.99	0.73	1.35
F	16.5	17.4	22.5	0.95	0.73	1.29
G	20.6	18.3	27.5	1.12	0.75	1.50
H	18.9	19.0	29.1	0.99	0.65	1.53
I	16.5	15.1	32.9	1.09	0.50	2.18
J	18.1	18.6	24.7	0.98	0.73	1.33
K	24.7	24.6	33.9	1.01	0.73	1.38
L	27.2	25.1	30.9	1.09	0.88	1.23
M	32.5	33.0	38.0	0.99	0.86	1.15
N	29.1	21.0	29.1	1.39	1.00	1.39
O	20.2	20.4	30.9	0.99	0.68	1.51
P	25.6	25.1	41.2	1.02	0.62	1.64
Q	27.8	26.8	35.3	1.03	0.79	1.32
R	24.7	18.2	35.3	1.35	0.70	1.93
S	31.5	24.8	32.9	1.27	0.96	1.33
T	25.1	23.5	31.6	1.07	0.79	1.35
Mean	22.7	21.0	31.0	1.08	0.73	1.51
SE	1.1	1.0	1.1	0.03	0.03	0.06
Lightest	16.5	15.1	22.5	1.39	1.00	2.18
Heaviest	32.5	33.0	41.2	0.95	0.50	1.15

Similarly there was no relationship between the ratio of the owner assessed grazing capacities to the pre-1989 Department of Lands rated carrying capacities (average 0.73, range 1.00 to 0.50) and property or flock size (Figs 3c and 3d). On all twenty properties the owner assessed grazing capacity was more conservative than the pre-1989 Department of Lands rated values (Table 2).

The ratio of Department of Lands rated carrying capacities to the model's (average 1.51, range 2.18 to 1.15) was not related to property or flock size (Figs 3e and 3f). On all 20 properties the pre-1989 Department of Lands rated carrying capacities were heavier than the model's 'safe' grazing capacity (average 50% heavier) (Table 2).

Discussion

Graziers as consultants

Employing experienced graziers as consultants to evaluate and assist in refining a model for objectively estimating grazing capacities was a positive step towards gaining community

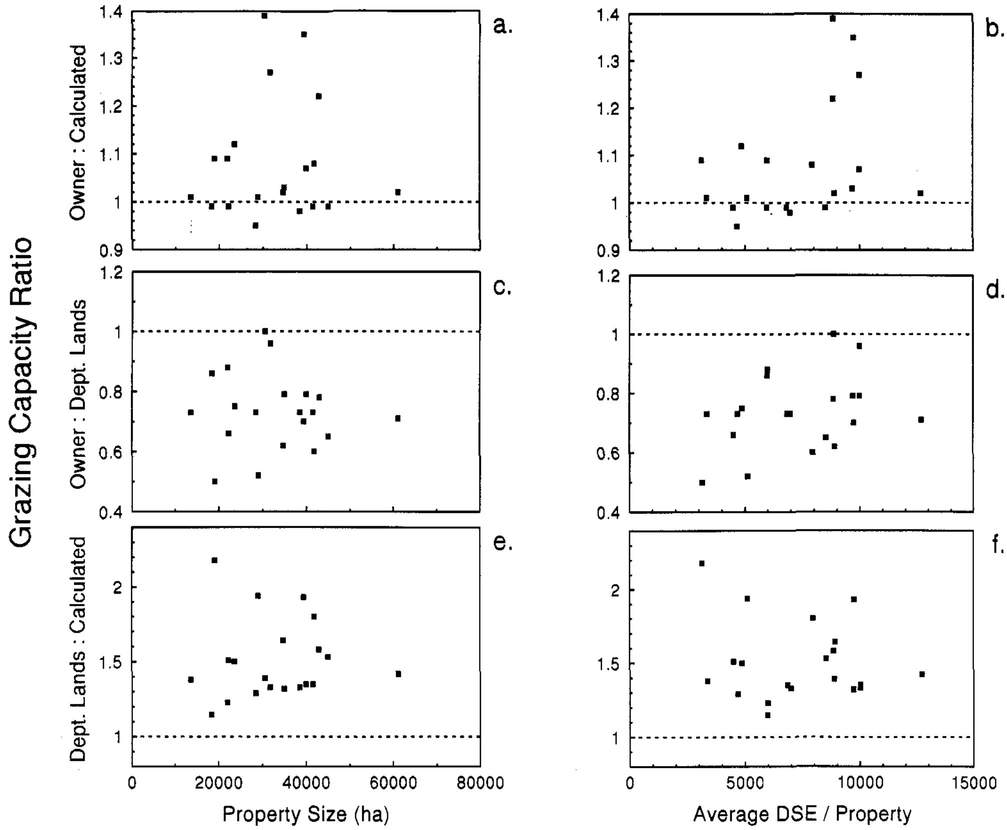

Fig. 3. Comparison of livestock ratios (a) owner assessed grazing capacities: calculated grazing capacity and property size, (b) owner assessed grazing capacities: calculated grazing capacity and flock size, (c) owner assessed grazing capacities: Department of Lands rated carrying capacities and property size, (d) owner assessed grazing capacities: Department of Lands rated carrying capacities and flock size, (e) Department of Lands rated carrying capacities: calculated grazing capacity and property size and (f) Department of Lands rated carrying capacities: calculated grazing capacity and flock size for 20 grazing properties in south-west Queensland selected by two grazier consultants applying and evaluating a model for estimating 'safe' long-term grazing capacities of individual properties.

confidence in the review of carrying capacities in south-west Queensland. As experienced graziers, the consultants had established links within the grazing community. Using these links and assurance of confidentiality, the consultants were able to build confidence and discuss concerns regarding the model using their own personal 'grazier' terminology.

The money and time invested training graziers as consultants was considered well spent based on the success of introducing, evaluating and refining the model in the grazing community of south-west Queensland. With both the grazier consultants and researchers, use of a common terminology expedited discussion and identification of problems in the model as they arose. This highlighted a valuable and innovative role that can be played by experienced graziers in linking science and practice.

In tackling sensitive issues such as grazing capacities, the approach described here may serve as a model for dealing with other issues. A comparable approach is currently being proposed to investigate long-term property grazing capacities in the Desert Uplands region of central

Queensland (G. Edwards and A. Caltabiano, pers. comm.). While this approach did not conform to the participatory model of technology transfer as described by Jiggins (1993), the employment of the grazier consultants was considered appropriate and useful in developing partnerships among researchers, extensionists, graziers, financiers and administrators.

Land condition

The model assessed only tree and shrub cover as an indicator of land condition. Surveys at a regional scale where these or other forms of land condition data were recorded are rare in south-west Queensland. In three previous regional scale surveys, Dawson and Boyland (1974), Mills *et al.* (1989) and Passmore and Brown (1992) used different techniques to those used by the grazier consultants, making it difficult to compare the present results with those earlier surveys.

Use of grazing capacities

The estimate of a 'safe' long-term grazing capacity for an individual property provides a valuable target around which seasonal livestock numbers on a property could be expected to fluctuate following responsive management. At this scale, grazing capacity information is of value to land administrators and to those purchasing properties.

However, for land managers, decisions regarding livestock generally occur at the paddock level. For the 'safe' grazing capacity concept to be most useful to land managers, grazing capacities for individual paddocks must be estimated using the same principles and procedures as for the whole property.

When applied at the paddock scale, the grazing capacity estimate could provide a target around which tactical decisions regarding seasonal stocking rates could be based. A paddock scale 'safe' long-term grazing capacity is therefore more aligned to practical livestock management. It is at this scale where sustainable resource management decisions are made and implemented.

Ratio of owner assessed grazing capacities to calculated 'safe' grazing capacities

A significant relationship between the owner's assessed grazing capacity and the calculated grazing capacity indicated the model was capable of estimating a grazing capacity for the 18 'reasonably managed' properties selected. Whether the calculated grazing capacity or the owner assessed capacity is correct is difficult to determine without detailed comparisons of land condition between the selected properties and other properties in the region. With a lack of current regional scale surveys of land condition, this study must rely on the consultants' experience that the properties were 'reasonably managed' and an assumption that they were in reasonable condition. Based on this assumption this preliminary evaluation supports further development and a cautious, broader application of the model. This is currently occurring in two activities being conducted under a regional reconstruction initiative in south-west Queensland (Williams 1995).

Ratio of Department of Lands rated carrying capacities to the calculated 'safe' grazing capacities and to the owner assessed grazing capacities

The greatest variation in grazing capacities occurred between those calculated by the grazier consultants using the model of Johnston *et al.* (1996) and the pre-1989 Department of Lands rated carrying capacities. These results support anecdotal evidence that Department of Lands pre-1989 rated carrying capacities were less conservative than those practised in the grazing community (P.R. Tannock, pers. comm.). The fact that neither property size nor flock size was related to the ratio of average owner assessed or calculated capacities to the Department of Lands rated capacities suggests the issue is not confined to property size. This highlights the difficulties in examining grazing capacities of properties in south-west Queensland or any region. Careful consideration needs to be given to the presentation of the data and how it is interpreted as recommended by Heady and Child (1994).

Differences may be due to the Department of Lands capacities not reflecting either change in land condition or change in grazing practices. Pre-1989 values were determined from early settlement up to the 1940s and 1950s. In 1989, an attempt was made in south-west Queensland to review these capacities. This review was based on a response to perceived long-term changes in land condition and a recognition that actual grazing practice was not aligned to the values on record with the Department of Lands for many properties.

The Department of Lands is at the front-line in government land administration. If the Department of Lands adopts the model evaluated here by the grazier consultants, 'safe' grazing capacity estimates used by the Department may become more responsive and may better reflect change in land condition. There will also be a greater likelihood that the values the Department uses will more closely reflect grazing practice. For land administrators, the end result will be greater confidence in the information base. This will lead to more informed decisions regarding sustainable land management and administration. For land managers, there will be greater credibility for the information used by land administrators in decision making affecting properties and livelihoods.

The future

As identified in Johnston *et al.* (1996) there is room for improvement in the model and several areas were identified by these authors. While the model is currently being applied to individual properties in south-west Queensland on a voluntary basis, there is an active and on-going process of refining the methodology. This includes areas identified by the grazier consultants listed in this paper. Refinements also include an examination of the contribution made by non-domestic herbivores to 'safe' grazing capacity calculations. While not an area identified by the grazier consultants, improved grazing land management in south-west Queensland will increasingly need to focus on the management of total grazing pressure in order to achieve appropriate resource use. At the current stage of development the methodology provides a formal framework for examining long-term 'strategic' decisions regarding both domestic and non-domestic herbivores. A strength of this framework is the ability to link information from a variety of sources representing the combined experience of graziers, researchers, extension officers, land administrators and financiers.

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It was a pleasure to work with the three grazier consultants, Donald Cooney, Robert Crichton and Donald McLean throughout this activity. The strong cooperation between a number of Queensland government agencies and the participating graziers was also appreciated. Development of the 'safe' grazing capacity model has drawn on a large number of wide ranging and sometimes unrelated research activities conducted in the semi-arid woodlands of eastern Australia. To the graziers, agency staff and funding bodies who drove this work, thanks. It needs to keep going.

Note: In April 1996 The Queensland Department of Lands was re-named the Queensland Department of Natural Resources.

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