STOCKING RATE DECISION TOOLS FOR RANGELAND PASTORALISTS

MILESTONE 3 & FINAL REPORT

APRIL 2006

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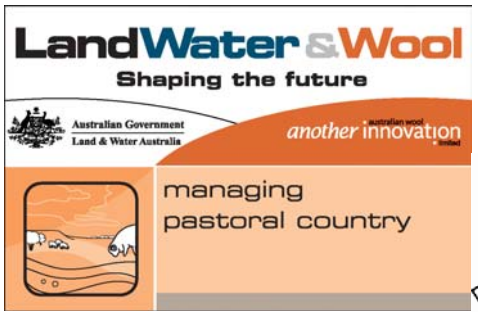

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

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MILESTONE NO.:	3	**DATE OF FINAL REPORT:**	30 April 2006
LWA PROJECT REFERENCE NO.:	DAN 23		
PROJECT TITLE:	Stocking rate decision tools for rangeland pastoralists		
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OTHER COLLABORATORS:	Mr Brian Marshall Holistic Management Educator 'Tara' (PO Box 300) Guyra NSW 2365		
PROJECT OBJECTIVES	1. Evaluate by simulation the behaviour and interpretation of grazing charts under ideal management 2. Present the results of the evaluation, and at least one other method of stocking rate assessment, to a minimum of 5 focus groups (25 pastoralists) in the Western Division of NSW 3. Collate graziers' assessments of stocking rate tools based on focus group discussions and on-property trials.		
MILESTONE :	***Components*** 1. Completion of on-property evaluations 2. Completion of final focus groups 3. Communication of results completed or in train 4. Submission of final report outlining the core tasks above		
ACHIEVEMENT RESULTS FOR COMPONENT 1:	***Completion of on-property evaluations*** On-property evaluations of the stocking rate tools developed by the project, or available for trial by co-operators, have not been possible due to drought conditions in western NSW. This possibility was foreshadowed in Milestone 2 (May 2005) which noted (p.18) that '..... *the serious and deteriorating drought situation throughout western NSW could be expected to severely limit the opportunities to engage pastoralists in the focus groups planned for the remainder of the project.'* In fact, considerable interaction with graziers did occur in the latter part of the project, as discussed under component 2 below, resulting in nine individuals volunteering to undertake on-property evaluations of one or more of the three stocking rate decision tools available (the 'benchmark' method, the 'Glove Box Guide' method and the 'forage square' or 'grazing area' method). Simplified instruction sheets and worksheets for these methods (Appendix 1), together with a covering letter, were mailed to these		

	individuals on 17 January 2006. Note that the on-property evaluations envisaged did not require a prolonged period of application of any technique. A 'desktop' evaluation may in some cases have sufficed to satisfy the co-operator of the utility of the tool. Where field observations were required, sufficient experience could probably have been gained in a day to allow an opinion to be formulated and any obvious deficiencies or difficulties identified. The need to complete only sufficient evaluations to form an opinion about the tools selected (rather than all of the assessments provided for in the worksheets) was made clear in the covering letter. Nevertheless, when contacted in late March 2006, none of the co-operators had commended their evaluations and all were preoccupied with the immediate tasks of drought management under difficult summer conditions. It was agreed with the Program Officer on 13 April 2006 that further extension of the project was not likely to result in the completion of these evaluations within a reasonable time frame.
ACHIEVEMENT RESULTS FOR COMPONENT 2:	***Completion of final focus groups*** As a result of potential legal implications arising from the evaluation of the DDH/100mm stocking rate index (as detailed in Milestone 2), and delays associated with their resolution, focus group discussions did not proceed as originally planned. Following the resolution of these issues an approach to grazier involvement was developed based around fewer and larger 'Grazing Management Update' workshops rather than the small focus groups originally proposed. Workshops were conducted at 'Bokhara Plains', Brewarrina on 7 October 2005 and at 'Furlong', Hillston on 17 October 2005. Promotion of these workshops was organised either by local NSW DPI staff in cooperation with a former Bestprac group ('Furlong') or by the landholder hosting the workshop ('Bokhara Plains'). Promotional material is included in Appendix 2. Workshops were presented jointly by Dr Ron Hacker and Holistic Management Educator Mr Brian Marshall. They were designed to provide an overview of both Holistic Management principles (particularly at the whole property level) and Tactical Gazing concepts (particularly at the paddock level), as well as an introduction to the three stocking tools which the project sought to evaluate. Further training options, and the opportunity to participate in on-property evaluation of one or more of the stocking rate tools, were also highlighted (see Appendix 2 for the workshop program). These workshops proved surprisingly popular and resulted in the involvement of more graziers than were originally expected to contribute to focus group discussions. A total of approximately 47 individuals participated in the two workshops, comprising approximately 35 from industry (graziers, partners and family members) together with agency and Catchment Management Authority staff. The reason for the good response to these workshops (despite poor seasonal conditions) cannot be determined with certainty but it seems likely that the opportunity to hear a Holistic Management educator, perhaps in conjunction with an agency researcher, was a considerable factor.

	Twenty five (25) workshop evaluations (Appendix 3) were returned from the two meetings. Summarised data from both workshops (Appendix 4) indicate that: • 80% of participants considered the ideas and material presented to be 'quite useful' or 'very useful'; • 92% of participants considered the material presented was 'OK', 'reasonably easy' to understand, or 'simple'; • 100%of participants considered the workshop worth recommending to friends. Specifically in relation to the stocking rate tools presented • 84%, 92% and 96% of participants, respectively, considered that the 'benchmark', 'glove box guide' and 'forage square' methods were 'OK' or better in terms of ease of understanding; • 80%, 88% and 92% of participants, respectively, considered that the 'benchmark', 'glove box guide' and 'forage square' methods were 'doable' or better in terms of practicality; • 72%, 76% and 80% of participants, respectively, considered that the 'benchmark', 'glove box guide' and 'forage square' methods would be of 'some benefit' or 'very beneficial' relative to their current approach to stocking rate estimation. All methods received more or less equal endorsement with no major deficiencies identified for any. While the failure of the on-property evaluations means that caution should be exercised in accepting these workshop results (which, of necessity, reflect only brief acquaintance with the methods) there is no reason why all of the tools proposed should not be taken forward to further evaluation and discussion with industry.
ACHIEVEMENT RESULTS FOR COMPONENT 3:	***Communication of results completed or in train*** The major technical findings of the project concern the performance of the DDH/100mm stocking rate indicator and the development of the 'benchmark' method of stocking rate estimation as a variation on this approach. These findings have been formally communicated to Resource Consulting Services in keeping with advice sought from the Legal Branch of NSW Department of Primary Industries. The results have also been communicated in discussion with two accredited Holistic Management Educators in NSW. Grazing management advice in western NSW is provided to pastoralists by individual Rangeland Extension Officers (located at Hay, Dareton, Broken Hill and Bourke), and through the 2-day 'Tactical Grazing' short course. This short course contains a section related to stocking rate assessment, based on the 'glove box guide' method as used in this project. Incorporation of other methods of stocking rate assessment, particularly the 'benchmark' method, into the Tactical Grazing course as an alternative to the 'glove box guide' method should be feasible and will be discussed with DPI staff responsible for the course. The findings of the project in relation to the DDH/100mm index (Appendix 5) will be prepared for publication in a peer reviewed journal, in keeping with the recommendations of the Sub-program review (February 2006). No further active promotion of these finding is intended until the manuscript is accepted for publication. This restriction, however, should not preclude

	progress towards the incorporation of the 'benchmark' method into the Tactical Grazing workshop.
ACHIEVEMENT RESULTS FOR COMPONENT 4:	***Submission of final report outlining the core tasks above*** This component is achieved by submission of this report.
SUMMARY OF PROJECT METHODS & MODIFICATIONS:	The original methodology proposed for this project involved: • Use of historical pasture growth simulation for several locations in western NSW to examine the performance of the DDH/100mm stocking rate indicator under 'ideal' management, and subsequently to develop guidelines for interpretation of the index in practice. • Evaluation, by a similar approach, of other simple indices of grazing pressure (eg DDH/100 mm of effective rainfall – derived by incorporation of vapour pressure deficit or pan evaporation into the original index). • Discussion of the potential benefits of these indices, after evaluation, with focus groups of pastoralists, together with other stocking rate tools currently available (eg the 'glove box guide method', Campbell and Hacker, 2000[1]; Holistic Management®[2] paddock monitoring and decision making framework) • Supporting cooperating pastoralists to implement one or other of the options on their properties and collation of their assessments. This methodology has been applied as described, with the exceptions that: • The deficiencies of the DDH/100mm index as a measure of correct stocking, and the emergence from this analysis of the simple 'benchmark' method of stocking rate assessment, resulted in the decision not to pursue the development of other indices based on 'effective rainfall'. Such indices would be expected to display similar properties to the conventional index and would be less practical because of the requirement to incorporate information not readily available. • Focus group discussions were replaced by 'Grazing Management Update' workshops, probably resulting in greater grazier participation. • Grazier assessment of stocking rate tools could be compiled only from workshop evaluations as widespread drought conditions prevented the completion of additional on-property evaluations.
STATEMENT OF RESULTS, THEIR INTERPRETATION AND PRACTICAL SIGNIFICANCE AGAINST EACH PROJECT OBJECTIVE:	***Objective 1 - Evaluate by simulation the behaviour and interpretation of grazing charts under ideal management*** *Results* • Under theoretically proper stocking, the DDH/100mm index does not closely track the benchmark value derived from long term carrying capacity and long term average annual rainfall. • Stocking rates derived from the benchmark value and the rainfall total over the preceding 12 months are closely related to those produced by applying a sustainable utilisation rate to simulated pasture growth over the same period, and produce similar levels of

[1] Campbell, T. and Hacker, R. (2000). The Glove Box Guide to Tactical Grazing Management for the Semi-Arid Woodlands. ISBN 0 7347 1195 6. NSW Agriculture.
[2] ® Allan Savory Centre for Holistic Management, Albuquerque, NM, USA

realised (actual) pasture utilisation.
- Under low rainfall conditions (12-monthly totals less than 120-150 mm depending on location) continuing application of stocking rates produced by either method can result in unacceptably high levels of realised utilisation
- Trends in the value of the index over two monthly periods are unlikely to have unambiguous value as indicators of impending feed deficits, despite apparent shifts in probability associated with rainfall and (at constant stocking rate) index trends at some locations.

Practical application
- Comparison of the DDH/100mm index, as derived from a grazing chart, with the (fixed) benchmark can lead to incorrect conclusions regarding the suitability of the current stocking rate and should be avoided.
- Use of the benchmark value in conjunction with the rainfall total for the preceding 12 months can provide a simple means (referred to as the 'benchmark' method) of estimating a proper stocking rate for comparison with the current actual stocking rate. This value will fluctuate widely, due to the wide variation in moving 12-month rainfall totals, but remains the most appropriate 'benchmark' for comparison with the actual situation.
- Pastoralists should understand and consult reputable seasonal climate forecasts, rather than trends in the index, as part of their assessment of likely medium term seasonal conditions. Part of this assessment should involve the forward projection of the12-monthly rainfall total for 3-6 months to determine if the system may be approaching a low rainfall period in which continued application of the calculated stocking rates could result in excessive pasture utilisation. Under these circumstances greater emphasis should be placed on the monitoring of paddock indicators.

Objective 2 - Present the results of the evaluation, and at least one other method of stocking rate assessment, to a minimum of 5 focus groups (25 pastoralists) in the Western Division of NSW.

Results
- Grazing Management Update workshops, combining presentations on Holistic Management and Tactical Grazing with an introduction to three methods of stocking rate assessment attracted more support from graziers than expected.
- Pastoralists considered there was little difference between the 'benchmark', 'glove box guide' and 'forage square' methods of stocking rate assessment in terms of their comprehensibility, practicality and capacity to contribute to improved management decision making.

Practical application
- Some further testing of the reliability of both the glove box guide and forage square methods would be desirable since these were not subject to detailed theoretical evaluation as part of this project. However, assuming a positive outcome there is no reason why all could not be promoted as reasonable alternatives to pastoralists, with confidence that they would be accepted as practical management tools.

	Objective 3 - Collate graziers' assessments of stocking rate tools based on focus group discussions and on-property trials. *Results* • Graziers' assessments of the stocking rate tools as presented at the Grazing Management Update workshops have been outlined above. • On-property trials could not be completed due to the impact of drought conditions in western NSW. *Practical application* • See objective 2 above
OUTLINE HOW THESE OUTPUTS CAN BE ADOPTED:	The major means by which these results can be adopted are: • Publication of the results obtained under Objective 1 in the peer-reviewed scientific literature, followed by promotion of the major findings in extension publications such as the Western Division Newsletter; • Promotion of the results to Rangeland Extension Officers within NSW DPI; • Incorporation of the findings into the Tactical Grazing short course in NSW; • Interaction with other projects within the Pastoral Sub-Program to extend the major findings to other states, following acceptance of a peer reviewed manuscript for publication.
SUMMARY OF COMMUNICATION, TECHNOLOGY TRANSFER OR 'ADOPTION' ACTIVITIES TO DATE:	• Presentation of preliminary results at NSW Department of Primary Industries rangelands strategic planning meeting, April 2005. • Two meetings to present results to commercial consultants (3 consultants directly involved, others involved through internal circulation of material provided). • Presentation of results, together with broader grazing management principles, at 2 Grazing Management Update workshops in western NSW– total attendance 47
ASSESSMENT OF ANY COMMERCIAL POTENTIAL:	Nil
LIST OF PUBLICATION TITLES:	Nil
WHERE CAN THE READER OF THIS REPORT OBTAIN ADDITIONAL INFORMATION	Additional information can be obtained from the Principal Investigator.
REFERENCES (if any):	Nil in main report
LIST OF ATTACHMENTS:	Appendix 1 Guidelines and work sheets for on-property evaluation of stocking rate assessment methods. Appendix 2 – Advertising flyers and workshop structure for Bokhara Plains and Furlong workshops. Appendix 3 - Workshop evaluation questionnaire. Appendix 4 – Analysis of evaluations from Bokhara Plains and Furlong workshops. Appendix 5 – Evaluation of the DDH/100mm stocking rate index
ABSTRACT (for AANRO):	Evaluation of the DDH/100mm (DSE days per ha per 100mm of rainfall) stocking rate indicator under theoretically ideal management indicated that comparison of this index with a fixed carrying capacity benchmark should

	not be used assist stocking rate decisions. However, stocking rates calculated by applying rolling 12-month rainfall totals to the carrying capacity benchmark are similar to those determined by application of a sustainable utilisation rate to annual pasture growth. This 'benchmark method' of stocking rate estimation could thus be a useful tool, allowing establishment of a 'dynamic benchmark' for comparison with the actual stocking rate. Because calculated stocking rates are based on past seasonal conditions and applied under future conditions even 'proper' stocking rates may lead to excessive utilisation if applied uncritically during periods of low rainfall (12-monthly total of 120-150mm depending on location). To help avoid these situations, pastoralists should project the rolling 12-month rainfall total forward for 3-6 months, based on climatological data or seasonal climate forecasts, to assess whether they are approaching such a period, and if so place increasing emphasis on pasture monitoring. Analysis of trends in rainfall prior to dry spells, which will be associated with complimentary trends in the DDH/100mm index at constant stocking rate, suggest that they have no general significance as indicators of impending feed deficits. Graziers in western NSW presented with the 'benchmark' method and two alternative approaches to stocking rate assessment (the 'glove box guide' and 'forage square' methods) expressed no clear preference and most considered that all had the capacity to contribute to improved decision making.

SUMMARY STATS FOR ENTIRE PROJECT PERIOD: **Reporting period: from 30/11/2004 to 31/4/2006…**						
NO. FIELD SITES:	0	**NUMBER OF PRESENTATIONS OR BRIEFINGS ON YOUR PROJECT:**				5
TYPES OF FIELD SITES:	No field sites; computer based simulations and workshops					
NUMBER OF PUBLICATIONS:	***Research***		***Extension***		***Journals***	
	Books		***Brochures***		***Other***	
NUMBER OF FIELD DAYS ETC., ATTENDANCE AND PROFILE OF PARTICIPANTS	***Field days:***		***No. woolgrowers:***		***No. of service providers:***	
	Courses:		***No. woolgrowers:***		***No. of service providers:***	
	Workshops:	2	***No. woolgrowers:***	35	***No. of service providers:***	12
HAVE YOU ESTABLISHED ALLIANCES WITH OTHER PROJECTS/PROGRAMS?	• Resource Consulting Services (RCS Coffs Harbour) • Holistic Management educators • NSW DPI: Presentation to Rangelands R&D Officers and DPI Strategic Planning Groups					
OTHER PROJECT ACTIVITIES (EG: PHOTO SHOOTS, FINANCIAL ANALYSIS, MEDIA ARTICLES):						
HAS YOUR PROJECT GOT ANY EXAMPLES OF INNOVATIVE ACTIVITIES?	• Computer-based simulation using historical climate data to evaluate grazing index under ideal management. • Collaboration with Holistic Management educator to deliver grazing management information and project results in workshop format • Direct interaction with private consultants (RCS and Holistic Management Educators Marshall and Gardiner) to discuss project results.					
HAVE YOU RECEIVED ANECDOTAL FEEDBACK ON YOUR PROJECT (OR THE LWW PROGRAM IN GENERAL)?	Sub Program review considered project results were of value to wool growers and should be published in peer reviewed journal.					
IS THERE DEMAND FOR PRODUCTS FROM YOUR PROJECT?	**WHAT?**	Stocking rate tools				
	HOW MANY?	3 - stocking rate assessment tools (only 1 developed by the project)				
	FROM WHOM?	Woolgrowers – 9 agreed to undertake evaluations of stocking rate tools but were unable to complete due to seasonal conditions.				
DO YOU HAVE EVIDENCE THAT:	**Eg: statistics and anecdotes from Field Day evaluation forms**					
(A) THE TARGET AUDIENCES FOR YOUR PROJECT'S ACTIVITIES AND PRODUCTS FIND THEM USEFUL?	Based on 25 workshop evaluation returns: • 80% of participants considered the ideas and material presented to be 'quite useful' or 'very useful'; • 80%, 88% and 92% of participants, respectively, considered that the 'benchmark', 'glove box guide' and 'forage square' methods were 'doable' or better in terms of practicality; • 72%, 76% and 80% of participants, respectively, considered that the 'benchmark', 'glove box guide' and					

	'forage square' methods would be of 'some benefit' or 'very beneficial' relative to their current approach to stocking rate estimation.
(B) AS A RESULT OF YOUR PROJECT, WOOLGROWERS HAVE A GREATER UNDERSTANDING OF THE PARTICULAR NRM ISSUE YOUR PROJECT IS DEALING WITH?	Based on 25 workshop evaluation returns: • 84%, 92% and 96% of participants, respectively, considered that the 'benchmark', 'glove box guide' and 'forage square' methods were 'OK' or better in terms of ease of understanding;
(C) AS A RESULT OF YOUR PROJECT, WOOLGROWERS ARE MOTIVATED TO ADOPT BETTER PRACTICES?	Based on 25 workshop evaluation returns: • 72%, 76% and 80% of participants, respectively, considered that the 'benchmark', 'glove box guide' and 'forage square' methods would be of 'some benefit' or 'very beneficial' relative to their current approach to stocking rate estimation. • 9 wool growers expressed interest in undertaking on-property evaluations of various stocking rate tools
(D) AS A RESULT OF YOUR PROJECT, WOOLGROWERS BELIEVE THEY HAVE AN INCREASED ABILITY TO ACT ON THE NRM ISSUE YOUR PROJECT IS DEALING WITH?	Based on 25 workshop evaluation returns: • 72%, 76% and 80% of participants, respectively, considered that the 'benchmark', 'glove box guide' and 'forage square' methods would be of 'some benefit' or 'very beneficial' relative to their current approach to stocking rate estimation.

Appendix 1 - Guidelines and work sheets for on-property evaluation of stocking rate assessment methods

THE BENCHMARK METHOD

STEP 1 - DETERMINE THE BENCHMARK (BM)

$$\text{BM (DSE/ha/100 mm)} = 100 \times \left\{ \frac{\text{LONG TERM CARRYING CAPACITY (DSE/ha)}}{\text{LONG TERM AVERAGE RAINFALL (mm)}} \right\}$$

Note: Calculate this benchmark to at least two decimal places. If you wish you can express long term average rainfall in points (eg 800 points for 8 inches) and long term carrying capacity in sheep/ha or ha/sheep

STEP 2 – CALCULATE THE PROPER STOCKING RATE FOR THE LAST 12 MONTHS RAINFALL

Proper Stocking Rate (DSE/ha) = BM x (rainfall for the last 12 months/100)

STEP 3 – CALCULATE THE PROPER NUMBER OF ANIMALS TO HAVE ON HAND NOW

Proper number of animals (DSE) = Proper stocking rate (DSE/ha) x area of property (ha)

Note that the ‘proper number’ will fluctuate widely depending on rainfall over the last12 months.

STEP 4 – COMPARE PROPER NUMBER WITH CURRENT NUMBER

Action should only be considered if the actual stock number is above the proper stock number

WORKSHEET FOR CALCULATING PROPER STOCKING BY THE BENCHMARK METHOD

PADDOCK	AREA (ha)	12mth RAIN (to end of last month)	BENCHMARK DSE/ha/100mm	STOCK NUMBERS									
				MONTH:		MONTH:		MONTH:		MONTH:		MONTH:	
				ACTUAL	PROPER	ACTUAL	PROPER	ACTUAL	PROPER	ACTUAL	PROPER	ACTUAL	PROPER
WHOLE PROPERTY													

PADDOCK	AREA (ha)	12mth RAIN (to end of last month)	BENCHMARK DSE/ha/100mm	STOCK NUMBERS									
				MONTH:		MONTH:		MONTH:		MONTH:		MONTH:	
				ACTUAL	PROPER	ACTUAL	PROPER	ACTUAL	PROPER	ACTUAL	PROPER	ACTUAL	PROPER
WHOLE PROPERTY													

THE 'GLOVE BOX GUIDE' METHOD

STEP 1 -Determine the *available forage on hand* (Factor 1) relative to this time last year.

- For each type of forage listed in the work sheet table rate the amount present now relative to this time last year, bearing in mind the abundance of the various plant types, their growth, palatability, feed quality, and current level of utilisation. (Be sure to rate the ***actual*** amount relative to last year not the proportional change)

- Rate the availability as
  1= *much less than this time last year*;
  2= *less than last year*;
  3= *about the same as last year*;
  4= *more than last year*;
  5 = *much more than last year.*

- Factor 1 = 1 if the amount of forage available now is about the same as this time last year.

STEP 2- Determine the *Seasonal Factor* (Factor 2*)* to describe the expected growing conditions over the coming year relative to those which produced the available forage on hand.

- Rate the seasons in the work sheet table as:
  1= *very poor*;
  2 = *poor;*
  3= *average;*
  4= *good;*
  5= *very good*

- Ratings for next year of 1 and 2 are conservative, 4 and 5 are a high risk approach. Unless long range weather forecasts are suggesting otherwise you'd most likely rate expected seasons as '3'.

STEP 3- Determine the *paddock condition factor* (Factor 3) to estimate how stocking needs to vary to meet pasture management targets.

- To determine this factor you need to have established a management objective for the paddock and worked out your management targets to achieve it (e.g. desired level of pasture utilisation or ground cover).

- In the box on the work sheet list the management target that you have established for the paddock.

- In column 1 of the work sheet table rate the current status of the paddock against the target. Rate the current status as:
  1= *much worse than target;*
  1.5= *worse than the target;*
  2= *about on target;*
  2.5= *better than target;*
  3= *much better than target.*

- In Column 2 enter the rating that will balance the rating in Column 1 to give an average of 2. For example if the paddock condition this year is worse than target (**1.5**) then to get an average of two (**2**) we need to rate next year as better than average (**2.5**).

  You may feel that the coming year is an opportune time to make large gains in the condition of the paddock in which case you should give **Column 2** a higher rating than is necessary to achieve a balance of two.

STEP 4- Determine the *total grazing pressure factor* (Factor 4) as a measure of the grazing the paddock has received over the last year

- This factor is the average number of dry sheep equivalents, including non-domestic animals, which the paddock has carried over the last 12 months
- Enter the average number of dry sheep equivalents carried for the last 12 months in the table on the work sheet.
- Estimate the average level of non-domestic grazing supported over the last 12 months, also in dry sheep equivalents, and enter in the table on the work sheet.

Now estimate the appropriate number of stock to be carried for the next 12 months.

CALCULATION 1: Calculate carrying capacity for the next 12 months as Total Dry Sheep Equivalents

- Combine Factors 1, 2, 3 and 4 to calculate the Total Dry Sheep Equivalents this paddock should carry over the next 12 months.

CALCULATION 2: Determine how much of the carrying capacity is available for domestic livestock

- Adjust the figure for non-domestic grazers from Step 4 up or down if this is likely to change much over the coming year (eg due to control measures).
- Subtract this figure from the Total Dry Sheep Equivalents (Calculation 1) to determine the carrying capacity available for domestic stock.

CALCULATION 3: Determine the number of stock to place in the paddock

- If more than one type of stock will be paced in the paddock split the number of domestic DSEs (calculation 2) into the desired proportions. Divide the available DSEs for each stock type by the appropriate conversion factor (1 beast = 10 DSE) to convert to actual stock numbers.

GLOVE BOX GUIDE STOCKING RATE WORK SHEET

PADDOCK …… **AREA (ha)** …… **DATE**……

STEP 1- FORAGE AVAILABILITY FACTOR

FORAGE TYPE	RATING
Palatable perennial grasses	
Winter annuals	
Summer annuals	
Palatable shrubs	
Copper burrs	
TOTAL (Divide total by 15)	____ 15*

FACTOR 1

- If some of these forage types never grow in the paddock, or are never present at this time of year, reduce 15 by 3 for every missing type e.g. if palatable shrubs are never present divide the total by 12 (i.e. 4x3).

STEP 2 - SEASONAL FACTOR

	Column 1		Column 2
Previous Season (12-6 months ago)		Expected next season (now-6 months hence)	
Season just gone (6 months ago-now)		Expected following season(6-12 months hence)	
Total over last 12 months to now		Total for coming year	
	Seasonal Factor =	Total for coming 12 months (Col 2) / Total for last 12mths (Col 1)	

FACTOR 2

STEP 3 - PADDOCK CONDITION FACTOR

Paddock Management Target e.g.: *level of utilisation of perennial grasses not to exceed 30% or soil cover not to drop below 40 %*	

COLUMN 1 Current status	COLUMN 2 Required status	COLUMN 3 Paddock Condition Factor = column 1 / column 2

FACTOR 3

STEP 4 - TOTAL GRAZING PRESSURE FACTOR

Enter the average number of livestock DSEs carried over the last 12 months and estimate the number of non-domestic grazers relative to domestic stock, also in DSEs.

	Average DSE over last 12 months
Domestic livestock	
Non-domestic grazers	
TOTAL	
	FACTOR 4

CALCULATIONS

1. TOTAL DRY SHEEP EQUIVALENTS

Forage Availabilit	Seasonal Condition	Paddock Condition	Total grazing pressure	Total Dry Sheep Equivalents
	×	×	×	=
Factor 1	Factor 2	Factor 3	Factor 4	

2. DOMESTIC CARRYING CAPACITY

	—		=
Total Dry Sheep Equivalents (Calculation 1)		**Non-domestic Dry Sheep Equivalents**	**Number of Domestic Dry Sheep Equivalents**

3. NUMBER OF STOCK

SHEEP/ GOATS		÷		=
CATTLE		÷		=
	Dry Sheep Equivalents available for livestock		**DSE conversion factor for stock class**	**Number of stock to run**

GLOVE BOX GUIDE STOCKING RATE WORK SHEET - WORKED EXAMPLE

PADDOCK Anyone **AREA (ha) ……** **DATE……**

STEP 1- FORAGE AVAILABILITY FACTOR

FORAGE TYPE	RATING
Palatable perennial grasses	4
Winter annuals	5
Summer annuals	-
Palatable shrubs	3
Copper burrs	4
TOTAL	16
(Divide total by 15)	~~15*~~ 12
	1.3

FACTOR 1

***** If some of these forage types never grow in the paddock, or are never present at this time of year, reduce 15 by 3 for every missing type e.g. if palatable shrubs are never present divide the total by 12 (i.e. 4x3).

STEP 2 - SEASONAL FACTOR

	Column 1		Column 2
Previous Season (12-6 months ago)	2	Expected next season (now-6 months hence)	3
Season just gone (6 months ago-now)	5	Expected following season(6-12 months hence)	3
Total over last 12 months to now	7	Total for coming year	6
	Seasonal Factor =	Total for coming 12 months (Col 2) / Total for last 12mths (Col 1)	0.9

FACTOR 2

STEP 3 - PADDOCK CONDITION FACTOR

Paddock Management Target e.g.: *level of utilisation of perennial grasses not to exceed 30% or soil cover not to drop below 40 %*	*Min. ground cover 40%*

COLUMN 1	COLUMN 2	COLUMN 3
Current status	**Required status**	**Paddock Condition Factor = column 1 / column 2**
2.5	**2**	**1.3**

FACTOR 3

STEP 4 - TOTAL GRAZING PRESSURE FACTOR

Enter the average number of livestock DSEs carried over the last 12 months and estimate the number of non-domestic grazers relative to domestic stock, also in DSEs.

	Average DSE over last 12 months
Domestic livestock	4000
Non-domestic grazers	1000
TOTAL	5000
	FACTOR 4

CALCULATIONS

1. TOTAL DRY SHEEP EQUIVALENTS

Forage Availabilit		Seasonal Condition		Paddock Condition		Total grazing pressure		Total Dry Sheep Equivalents
1.3	×	0.9	×	1.3	×	5000	=	7605
Factor 1		Factor 2		Factor 3		Factor 4		

2. DOMESTIC CARRYING CAPACITY

7605	—	1000	=	6605
Total Dry Sheep Equivalents (Calculation 1)		Non-domestic Dry Sheep Equivalents		Number of Domestic Dry Sheep Equivalents

3. NUMBER OF STOCK

SHEEP/ GOATS	5000	÷	1.2	=	4167	
CATTLE	1605	÷	10	=	160	
	Dry Sheep Equivalents available for livestock		DSE conversion factor for stock class		Number of stock to run	

WORKSHEET FOR CALCULATING PROPER STOCKING BY THE GLOVE BOX GUIDE METHOD

MONTH:	PADDOCK									WHOLE PROPERTY
FACTOR 1 - FORAGE AVAIL										
FACTOR 2 - SEASON										
FACTOR 3 - PADDOCK CONDITION										
FACTOR 4 - TOTAL GRAZING PRESSURE										
NON DOMESTIC DSE										
TOTAL DSE (Calculation 1)										
Domestic DSE (Calculation 2)										
No. of Sheep/goats (Calculation 3)										
No. of Cattle (Calculation 3)										

MONTH:	PADDOCK									WHOLE PROPERTY
FACTOR 1 - FORAGE AVAIL										
FACTOR 2 - SEASON										
FACTOR 3 - PADDOCK CONDITION										
FACTOR 4 - TOTAL GRAZING PRESSURE										
NON DOMESTIC DSE										
TOTAL DSE (Calculation 1)										
Domestic DSE (Calculation 2)										
No. of Sheep/goats (Calculation 3)										
No. of Cattle (Calculation 3)										

MONTH:	PADDOCK									WHOLE PROPERTY
FACTOR 1 - FORAGE AVAIL										
FACTOR 2 - SEASON										
FACTOR 3 - PADDOCK CONDITION										
FACTOR 4 - TOTAL GRAZING PRESSURE										
NON DOMESTIC DSE										
TOTAL DSE (Calculation 1)										
Domestic DSE (Calculation 2)										
No. of Sheep/goats (Calculation 3)										
No. of Cattle (Calculation 3)										

THE 'FORAGE SQUARE' METHOD

STEP 1 - At a representative point in the paddock estimate the area of a square that would provide enough forage to feed one sheep for one day while leaving behind enough material to maintain ground cover and result in only a moderate level of utilisation. (Imagine yourself successfully filling a bag the size of an animal's stomach with only one hand, as a sheep with one mouth and no hands would. Remember you will be looking at all the vegetation and be aware that animals will be selecting their diets, taking leafy material of the season, some fibrous material and no old oxidizing material, and they only have a limited time to do so since they have to ruminate and sleep. Don't simply consider the bulk of forage present, but also its quality.)

Do this by marking one corner of the square, or having your partner stand at that spot, and then walking along the diagonal until you feel that the area is big enough to support one sheep for a day. Ideally repeat this for a number of locations to get a reasonable 'average square' for the paddock.

Compute the area of the average square by multiplying the length of two sides, and then divide that number into the number of square metres in one hectare (10,000). This will give you an estimated Animal Days per Hectare (ADH).

e.g.: The side of the average square is 10 m.
Area of the square is 10m x 10m = 100 sq m
$\frac{10{,}000 \text{ sq m}}{100 \text{ sq m}}$ = 100 ADH

STEP 2 - Calculate the number of sheep days of feed available in the paddock:

No of sheep days = Paddock area (ha) x ADH

e.g. 500 ha paddock x 100 ADH = 50,000 sheep days of feed available

STEP 3 - Calculate the number of days the feed will last for the number of stock on hand OR the number of stock that can be fed for a given period (assuming no more feed is grown)

e.g. for 500 head in the paddock, feed is sufficient for 50,000/500 = 100 days
for feed to last 120 days we can carry 50,000/120 = 416 sheep

Approximate Stocking Rate for whole property

Imagine a sheep property with a stocking rate of about 0.5 DSE/ha. That means 2 hectares for every sheep. To keep the numbers simple, assume you keep no lambs through a non-growth period which will last for 180 days. This means every 2 hectares has to supply 180 sheep days, or animal days (AD) of feed:

180 ADs ÷ 2 hectares = 90 ADs per hectare (ADH)
So 1/90th hectare must be able to feed one sheep for one day.

Now look at your land and see if one sheep could eat for one day on a selection of 1/90th hectare samples.

1 hectare = 10,000 square metres
1/90th hectare = 10,000 ÷ 90 = 111 square metres

Pushing the square-root button on a pocket calculator will quickly tell you that one side of a square covering 111 square meters is 10.5 metres. You can then step off several random squares and in each case ask: Could this square feed one sheep for a day? (It helps greatly if four people do the pacing and can stand at each corner while you judge whether the area could feed one sheep for a day).

You can also work the same problem the other way to find out what stocking rate your land can carry through a 'dry' season.
After a very dry summer, suppose you find that a square of 10 metres to a side will not feed one sheep for one day. Suppose you find that the square has to be at least 15 metres on each side. From this you can determine how many stock you must sell to get through the winter (or how many sheep days of feed you must buy):

15m x 15m = 225 sq m needed to feed one sheep for one day.
Therefore, to find out how many sheep one hectare would support for a day, you divide 10,000 (sq m in a hectare) by 225 (area required for one sheep) to give you the answer = 44 sheep (ADH).

If the property is 10,000 hectares, this supplies 440,000 ADs (44 ADH x 10,000 hectares = 440,000 ADs). Note: you need to subtract obvious areas such as roads or steep hillsides that will never be grazed from your total land area.

440,000 ADs feed only 2,444 sheep for 180 days (440,000 ADs ÷ 180 days = 2444 sheep).
If you normally run 5,000 sheep, you can expect them to run out of forage in about 90 days (440,000 ADs ÷ 5,000 sheep = 89 days).

Adapted from 'Holistic Management Workbook' Island Press 2006 by
Brian Marshall, Certified Educator for Holistic Management International ®

WORKSHEET FOR CALCULATING PROPER STOCKING BY THE FORAGE SQUARE METHOD								
MONTH:	**PADDOCK**							
AREA OF PADDOCK (HA) (A)								
SIDE OF SQUARE (m)								
AREA OF SQUARE (m^2) (B)								
No. OF SHEEP IN PADDOCK (C)								
SHEEP DAYS AVAILABLE = D = (A X 10,000)/B								
DAYS OF FEED AVAILABLE = D/C								
No. SHEEP TO BE FED (if different to C) (E)								
DAYS OF FEED AVAILABLE - D/E								
MONTH:	**PADDOCK**							
AREA OF PADDOCK (HA) (A)								
SIDE OF SQUARE (m)								
AREA OF SQUARE (m^2) (B)								
No. OF SHEEP IN PADDOCK (C)								
SHEEP DAYS AVAILABLE = D = (A X 10,000)/B								
DAYS OF FEED AVAILABLE = D/C								
No. SHEEP TO BE FED (if different to C) (E)								
DAYS OF FEED AVAILABLE - D/E								
MONTH:	**PADDOCK**							
AREA OF PADDOCK (HA) (A)								
SIDE OF SQUARE (m)								
AREA OF SQUARE (m^2) (B)								
No. OF SHEEP IN PADDOCK (C)								
SHEEP DAYS AVAILABLE = D = (A X 10,000)/B								
DAYS OF FEED AVAILABLE = D/C								
No. SHEEP TO BE FED (if different to C) (E)								
DAYS OF FEED AVAILABLE - D/E								

Appendix 2 – Advertising flyers and workshop structure for Bokhara Plains and Furlong workshops

Flyer prepared and distributed by Mr Graham Finlayson, Bokhara Plains, Brewarrina.

"Grazing Management"….

***Are you interested in attending a grazing management update??**
***Do you think you would benefit from a better decision making process next drought??**
***Would you like a free smoko & lunch and a chance to discuss these issues with your peers??**
***Come along to *"Bokhara Plains"* on Friday the 7th October at 9am.**

Guest Speakers: * Dr. Ron Hacker
Research Leader, Pastures
and Rangelands. NSW D.P.I.
***Brian Marshall**
HRM Educator, Guyra.

*****Also in the afternoon…***
The Twin Rivers Fire Brigade meeting and "new" fire truck inspection with information on its operation.
*****And finishing with….***
The "Culgoa Landcare Meeting" in the early evening, followed by a few refreshments.

****R.S.V.P by Monday the 3rd Oct. please for catering purposes.**
Contact: ***Graham & Cathy Finlayson***
Ph. 0268744921
Email: bokharaplains@bigpond.com.au

Flyer prepared and distributed by Ms Sally Ware, Rangeland Extension Officer, NSW Department of Primary Industries, Hay.

Grazing Management

With Ron Hacker (Research Leader, Pastures and Rangelands, NSW DPI, Trangie) and Brian Marshall, (HRM Educator, Guyra)

"Free workshop"

"Getting down to the paddock level and working out stocking rates for your country"

Date: Monday, October 17

Time: 9.00am for a cuppa with a 9.30am start

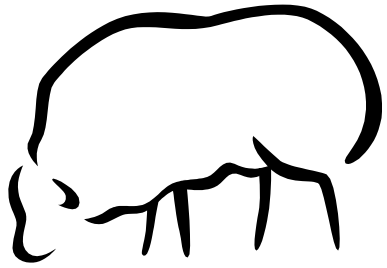
Location: Furlong woolshed

Catering: fund raiser for Merrowie Bush Fire Brigade

Afternoon session: Geoff Duddy, (Sheep and Wool Officer, NSW DPI): "Alternative sheep breeds for the western division"

RSVP to Jon and Naomi Vagg for catering: ph: 69678156

More questions? Sally Ware, NSW DPI Hay ph: 69931608



Workshop Program

GRAZING MANAGEMENT UPDATE
A half-day workshop by
Ron Hacker and Brian Marshall

Session 1 Taking a holistic view of the world

- Appreciating the unique opportunity of agriculture to harvest, package and market sunlight and rainfall.
- Understanding the relationship between plants, soil and animals and the importance of time in plant recovery or "rest".
- The nature of bio-diversity. That is, all the species, including people and the inter-relationship between them.
- The importance of perennials in landscapes and underlying principles.
- What are the issues for individuals or regions?
- Distinguishing between cause and effect.
- Fundamental ecosystem processes and the tools to manipulate them.
- What do land mangers want? What do we do to get what we want? How do we make decisions?

Session 2 Getting down to the detail at paddock level

- Pasture conditioning and the Tactical Grazing concept
- Assessment and monitoring techniques – getting feedback from the land
- Discussion of the possible application of management tools for which no local R and D results are available.

Session 3 Getting the stocking rate right - or matching pastures and animals

- Developing a grazing plan incorporating paddock strategies and practical management requirements
- Benchmark method
- Glove box guide method
- Forage square method
- Monitoring the key indicators
- Further training opportunities
- Feedback on methods and options for further evaluation

Appendix 3 - Workshop evaluation questionnaire

(Note: the same questionnaire was used for both the Bokhara Plains and Furlong workshops)

To help us improve the presentation of this material for future workshops we would be grateful if you could answer the following questions.

WORKSHOP USEFULNESS

1. How useful do you think the ideas and material contained in this workshop might be in assisting you to manage your business?

No Use	Little use	Useful	Quite useful	Very Useful

2. What information did you find particularly interesting or useful?

_____

3. What would you .like to hear more about?

_____

4. How easy was it to understand the material presented?

Difficult	Bit hard	OK	Reasonably easy	Simple

5. Do you have any suggestions on how the material could be better presented?

_____

_____

_____

6. Would you recommend this workshop to friends Yes/No

Any other comments?

_____

_____

_____

_____

STOCKING RATE ASSESSMENT METHODS

1. Ease of understanding – are the methods easy or difficult to comprehend?

Method	Difficult	Bit hard	OK	Reasonably easy	Simple
Benchmark					
Glove Box Guide					
Grazing area					

2. Practicality – are the methods practical to implement?

Method	No problems	Fairly easy to apply	Doable	A bit much	Completely impractical
Benchmark					
Glove Box Guide					
Grazing area					

3. Benefits – would the methods offer any advantage over, or complement, what you do now?

Method	Very beneficial	Some benefit	Perhaps	Doubtful benefit	No benefit at all
Benchmark					
Glove Box Guide					
Grazing area					

How do you make stocking rate decisions now?

Would you be interested in testing one or more of these methods for a few months and providing further feedback on their practicality? (Tick which method you would be interested in and provide your contact details)

Benchmark method ☐
Glove Box Guide method ☐
Grazing area method ☐

Contact details

THANK YOU FOR YOUR PARTICIPATION

NSW DEPARTMENT OF **PRIMARY INDUSTRIES**

Appendix 4 – Combined analysis of evaluations from Bokhara Plains and Furlong workshops

Workshop usefulness

Q1. How useful do you think the ideas and material contained in this workshop might be in assisting you to manage your business?

Response	N	%
No use	0	0
Little use	1	4
Useful	4	16
Quite Useful	17	68
Very Useful	3	12
TOTAL	25	100

2. What information did you find particularly interesting or useful?

Bokhara Plains	Furlong
• Ground cover graph • Pasture regeneration • Effects of grazing on perennials • How to work out stocking rates • Stocking rate and grass rehabilitation • Grazing management – plant growth - stocking rates • Ground cover • Most of the information presented • Stocking rates on ground cover • How to determine stocking rates • Stocking rate work sheets • Plant growth	• Overview of Grazing Management/Stocking Rates • Estimating plant cover • Pasture analysis • Method carrying capacity over future 12 months • How much land required for 1 stock unit • Grazing pressure • Stocking rates relating to pasture availability

3. What would you .like to hear more about?

Bokhara Plains	Furlong
• Stocking rates etc • Practical paddock demonstrations • Everything • Growing native grass • All aspects • Stocking rates • More detail on improving pasture using stock • Ground cover • Plant biology • Importance of taking advantage of rainfall events	• Holistic Grazing Management • Working out the 12 month carrying capacity • When to reduce stock numbers • Assessing stocking rates

Q4. How easy was it to understand the material presented?

Response	N	%
Difficult	0	0
Bit Hard	2	8
OK	12	48
Reasonably easy	10	40
Simple	1	4
TOTAL	*25*	100

5. Do you have any suggestions on how the material could be better presented?

Bokhara Plains	Furlong
• No • In field - more practical • More time. A lot of information quickly • Some information i.e. numbers are hard to calculate without a calculator • It was presented great, just a lot in one sitting • A bit more detail • Less detail on figures. More straightforward descriptions of stocking methods • Give more strategies what could be done re. animal impacts and time in paddock to achieve result and importance of rain events as trigger for recovery period and time to promote growth • No	• Over a longer period • Need local content/pictures

6. Would you recommend this workshop to friends?

Response	N	%
YES	25	100
NO	0	0
TOTAL	*25*	100

STOCKING RATE ASSESSMENT METHODS
Cell entries are - number of responses (%)

1. Ease of understanding – are the methods easy or difficult to comprehend?

Response	Benchmark	Glove Box Guide	Grazing area (Forage square)
Difficult	0 (0)	0 (0)	0 (0)
Bit hard	4 (17)	2 (8)	1 (4)
OK	7 (29)	9 (38)	9 (36)
Reasonably easy	9 (38)	12 (50)	13 (52)
Simple	4 (17)	1 (4)	2 (8)
TOTAL	24	24	25

2. Practicality – are the methods practical to implement?

Response	Benchmark	Glove Box Guide	Grazing area (Forage square)
No problems	3 (12)	3 (13)	4 (17)
Fairly easy to apply	9 (36)	6 (25)	11 (46)
Doable	8 (32)	12 (50)	7 (29)
A bit much	5 (20)	3 (13)	2 (8)
Completely impractical	0 (0)	0 (0)	0 (0)
TOTAL	25	24	24

3. Benefits – would the methods offer any advantage over, or complement, what you do now?

Response	Benchmark	Glove Box Guide	Grazing area (Forage square)
Very beneficial	3 (12)	3 (13)	4 (16)
Some benefit	15 (60)	15 (63)	16 (64)
Perhaps	3 (12)	5 (21)	3 (12)
Doubtful benefit	4 (16)	1 (4)	2 (8)
No benefit at all	0 (0)	0 (0)	0 (0)
TOTAL	25	24	25

How do you make stocking rate decisions now?

Bokhara Plains	Furlong
• Seasonal • On account of feed available • Grazing chart. Paddock monitoring • Generally wait for rainfall + availability of stock & what the short term future of growth looks like • Grazing charts • A combination of traditional and above • By the amount of rainfall + groundcover • Look at bit different than before • On the look of feed available and try to keep below stocking rate • Reviewed weekly with actual conditions and predictions • By looking at paddocks month by month • By the grazing area method • On feed and water availability. Strong belief in Savoury's principles • On rainfall and feed growth	• Rainfall & weather - Pasture growth - Destocked due to drought means financial constraints limiting restocking to full potential. Past experience on pasture response to rainfall important. • Non scientific - experience • Ask Jan • Better pasture analysis • Amount of edible plants in the paddock • Feed available • Availability of pasture • Evaluate individual paddocks re. cover, beneficial species, weather patterns • Visual assessment of paddocks, budget reviews for supplementary feeding, then movement of stock to sale or agistment

Would you be interested in testing one or more of these methods for a few months and providing further feedback on their practicality?

METHOD	No of co-operators
Benchmark	4
Glove Box Guide	5
Grazing area	5
Note: Total of 9 individual co-operators, some interested in testing more than one method	

Appendix 5. Evaluation of the DDH/100mm stocking rate index

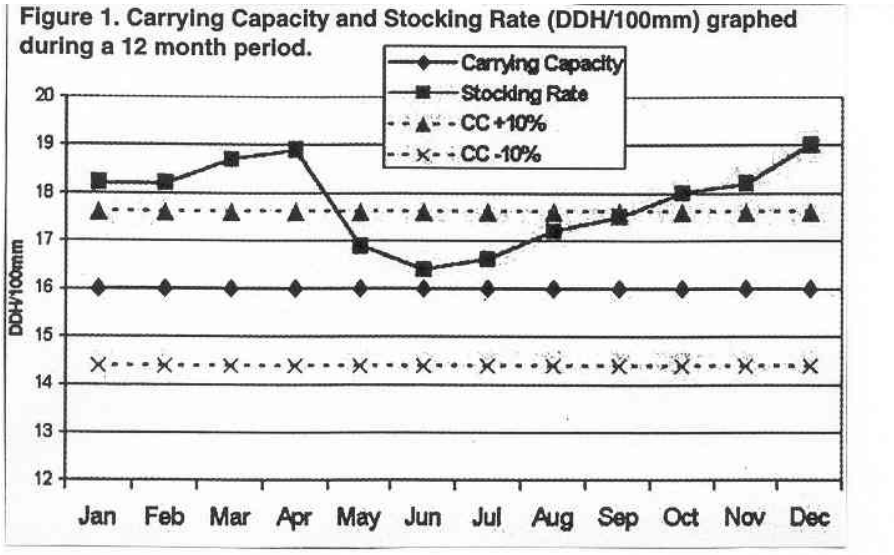
Introduction

Decisions regarding stocking rate over the whole property, or part of it, are the major means by which graziers match forage demand with forage supply. The requirement to manage this relationship (essentially, the management of total grazing pressure) is the fundamental issue underpinning sustainable pastoral production throughout the rangelands. Graziers routinely make these decisions, assisted by a wide variety of environmental cues (Carman *et al*. 1998). They also identify stocking rate (or buy/sell) decisions as the most important aspect of management that would benefit from improved seasonal forecasting capacity (Hacker *et al*., unpublished data). Any tool that will assist with this fundamental aspect of pastoral decision making has the potential to contribute significantly to the economic and ecological sustainability of the pastoral wool industry.

One approach to stocking rate decision making currently finding considerable support among graziers is based on the relative stocking rate index DDH/100mm (DSE days per ha per 100 mm of annual rainfall) (Bartle 2003, Martyn 2005). This indicator is used in conjunction with, and is derived from, a grazing chart which records the number of livestock-days of grazing in each paddock.

The use of this index has been explained in the following ways:

1. *The carrying capacity is shown as the blue line in Figure 1. The aim is to keep the stocking rate as close to this line as possible, allowing yourself about a 10% variation either side (the red lines in Figure 1).*



The DDH/100mm is normally calculated at the end of each month using a Grazing Chart and always has a full 12 months of information included in it i.e. is calculated on a rolling 12 months basis (Bartle 2003).

2. *Information from a grazing chart is used to calculate the previous 12 months actual stock numbers and rainfall, called the actual benchmark. This figure is then compared with the property's long-term average carrying capacity and average rainfall, known as the property's long term average carrying capacity benchmark. After being graphed, the trend is used along with the pasture monitoring to determine stocking levels.* (Martyn 2005)

Both authors make it clear that the 'long term average carrying capacity benchmark' or the 'carrying capacity', in DDH/100mm, is derived by dividing the long term average carrying capacity (essentially the long term average 'sustainable' stocking rate, expressed as DSE/ha) by the long term average annual rainfall.

Operation of the index in practice, according to these authors, thus involves either

- ongoing adjustment of stocking rate to keep the actual value of DDH/100mm, calculated over a moving 12 month window, within ± 10% of the benchmark (Bartle 2003); stated conversely, adjustment to stocking rate should be considered when ever the moving index falls outside the ± 10% bandwidth or
- pre-planned response to the trend in the index over two consecutive months, based on the claim that '…*a rising actual DDH/100mm for two consecutive months is a key indicator of an impending dry spell or feed deficit. It should initiate a series of pre-planned events – strategies that have been developed well in advance'* (Martyn (2005).

This 'conventional thinking' has been challenged by Guest and Guest (2005) who consider that the carrying capacity benchmark is better regarded as a 'ceiling' that should not be exceeded rather than a target since beyond this point rainfall rather than stock numbers determine the value of the index and the opportunity for 'control' is lost. They also consider that the carrying capacity benchmark needs to be fine tuned by comparing the 'critical date' achieved by extrapolation of the stocking rate trend (i.e. the date when the stocking rate index would be expected to cross the carrying capacity benchmark) with the date achieved by fodder budgeting.

Regardless of the *modus operandi*, the implication is that if a property is 'properly' stocked in relation to seasonal conditions, the running value of DDH/100 mm should closely track the carrying capacity benchmark. This provides a means of testing the performance of the index and assessing its value as a guide to stocking rate adjustment. Since the index has intuitive appeal, and is calculated from data that are readily collected on properties, its widespread application could have considerable benefits for the pastoral industry if its performance conforms to this criterion.

Methods

Estimation of carrying capacity

Long term data for daily pasture growth, derived from the WinGRASP model (Littleboy and McKeon 1997) were used to calculate the theoretical value of the carrying capacity benchmark, and the monthly values of the actual stocking rate index under 'proper' stocking, for three locations in western NSW.

Carrying capacity was calculated, after Johnston *et al.* (1996) as

$$CC = (a^* AAPG)/b \quad (1)$$

where

CC = carrying capacity (DSE/ha)

AAPG = average annual pasture growth (kg/ha).

a = 0.175 = the safe utilisation factor for annual pasture growth and

b = 400 = the annual dry matter intake (kg) per DSE.

The carrying capacity benchmark was thus calculated as

$$DDH/100mm_{(BM)} = (CC^*365)/(AAR/100) \quad (2)$$

where

AAR = average annual rainfall (mm).

Estimation of proper stocking rate

Daily pasture growth data were also used to estimate proper stocking rate on a monthly basis. Two general approaches to this problem are feasible. The first is to apply a sustainable utilisation percentage to pasture grown over some defined period, in a similar fashion to equation 1. The second is to assume that all forage grown in excess of a residual amount required for maintenance of the ecological system is available for consumption. It is easy to demonstrate that at reasonable levels of residual biomass (e.g. 300 kg/ka, the level below which intake of both livestock and kangaroos appears to be limited by forage availability; Short, 1987), the level of pasture utilisation that would be

required to consume all of the available pasture in relatively high rainfall years would be beyond what could reasonably be expected even in intensive grazing systems. On this basis the first approach is preferable. A combination of the two approaches, in which the level of utilisation is allowed to vary as a function of rainfall or pasture growth, might be a reasonable compromise but no objective data are available to define the required relationship.

The choice of time frame over which growth should be measured for stocking rate determination presents another set of compromises. A short time frame (say 1-6 months) has the advantage that stocking rate is determined on the basis of seasonal conditions close to the period in which the stocking rate is to be applied but the disadvantage that stocking would often be unrealistically suspended since no growth may occur for extended periods when, in practice, stocking can quite reasonably continue based on standing dry matter. A long time frame (say >1 year), on the other hand, has the disadvantage that not all pasture grown over an extended period may still be available to contribute to forage supply, and stocking rate is unduly influenced by seasonal conditions far removed from the period in which the calculated stocking rate will be applied.

For this study, a 12 month growth period was considered a reasonable compromise, with the advantage that short term fluctuations in stocking rate associated with seasonal growth patterns would be avoided. The sustainable utilisation approach, applied to growth accumulated over this period, was also adopted, recognising that the resulting stocking rates may be conservative relative to those that might reasonably be applied in years of high rainfall.

The 'proper' stocking rate (DSE/ha) for current seasonal conditions, SR_u , was thus calculated on the first day of each month by substituting in equation (1) the actual pasture growth for the immediately preceding 12 month period, ending the last day of the previous month i.e.

$SR_u = (a^* APG)/b$ (3)

where

SR_u = stocking rate based on pasture utilisation (DSE/ha)

APG = annual pasture growth for the preceding 12 months (kg/ha).

a = 0.175 = the safe utilisation factor for annual pasture growth and

b = 400 = the annual dry matter intake (kg) per DSE.

Model parameters and climate data

Several parameter sets, or calibrations, are available for the WinGRASP model. These were derived by the AussieGRASS project (Richards *et al.* 2001) and may be used in conjunction with daily climate data from the SILO data base to simulate pasture growth for a wide range of environments in western NSW.

In this project, daily pasture growth simulations were based on the following combinations of climate data and parameter set:

LOCATION (CLIMATE DATA SET)	AVERAGE ANNUAL RAINFALL (mm)	WinGRASP PARAMETER SET
Bourke	350	NSW Average
Cobar	375	NSW Average
Broken Hill	251	Kinchega

The simulations thus broadly covered the range of rainfall seasonality from slight summer dominance (Bourke), through aseasonal (Cobar), to slight winter dominance (Broken Hill) and a range of average annual rainfall values. The parameters sets used are those considered most appropriate for the selected locations. The 'Kinchega' set was derived from a location relatively close to Broken Hill and thus includes the growth response of winter growing annuals. The 'NSW average' set is considered

the most appropriate for Cobar and Bourke as it reflects winter growth better than other parameter sets derived from more northerly environments dominated by C4 grasses.

Proper stocking rate based on benchmark carrying capacity and rainfall

As an alternative to the pasture utilisation approach outlined above, the carrying capacity benchmark, DDH/100 mm $_{(BM)}$, was used in combination with 12-monthly rainfall to calculate the 'proper' stocking rate to be applied each month, SR_b. The calculation takes the form

SR_b = (DDH/100 mm $_{(BM)}$ * AR/100)/365 (4)

where

AR = total rainfall (mm) for the preceding 12 months and the subscript (b) denotes that the stocking rate is derived from the carrying capacity benchmark rather than pasture utilisation.

As with $SR_{(u)}$, the calculation of proper stocking rate was performed on the first day of each month, based on rainfall for the 12 month period to the end of the preceding month.

Calculation of the stocking rate index

The stocking rate index, DDH/100mm, for any12 month period was calculated as

$$DDH/100mm_{(u/b)} = \left(\sum_{i=1}^{12} (DDH_i) \right) / (AR/100) \quad (5)$$

where

$DDH/100mm_{(u/b)}$ = the stocking rate index for stocking rates determined by either the utilisation (u) or benchmark (b) methods

DDH_i = DSE days per ha accumulated in month i by application of the proper stocking rate (calculated by either the utilisation of benchmark methods)

AR = total rainfall (mm) for the 12 month period.

The set of DDH/100mm $_{(u/b)}$ values thus obtained represents the behaviour of the index under a theoretical 'proper' stocking regime in which stocking rate is adjusted monthly (on the first day of the month) on the basis either of pasture growth or rainfall over the preceding 12-months. If the index is a useful indicator of correct stocking, the expectation is that these sets of values will vary within a narrow range around the carrying capacity benchmark, in fact within ±10% of the benchmark value.

Realised pasture utilisation

Even when stocking rate is adjusted monthly in an attempt to balance forage supply and forage demand, the desired level of pasture utilisation will not necessarily be achieved because the proper stocking rate can only be determined on the basis of past conditions but is necessarily applied under future conditions. The level of pasture utilisation actually achieved (Realised Utilisation, RU) can thus only be determined retrospectively. Realised utilisation was calculated for the same 12-month periods used to calculate the actual stocking rate index by the formula

$$RU_{(u/b)} = \left(\sum_{i=1}^{12} (DDH_i)*400 / (365*TG) \right) *100 \quad (6)$$

where

RU = Realised Utilisation (%), with subscript (u) or (b) depending on the proper stocking rate used to calculate the other terms of the equation

TG = total pasture growth (kg/ha) for the 12 month period

and the summation represents the total DSE days per ha accumulated during the same period.

Biannual stocking rate adjustment

Because monthly stocking rate adjustment is impractical, the operation of the index was also evaluated under scenarios in which adjustment occurred only twice a year, in autumn and spring, a management scenario much more closely related to what might be achievable by graziers in western NSW. To simulate these scenarios, stocking rates were calculated by equations 3 and 4 on 1 April and 1 October, and held constant between these dates. The DDH/100mm$_{(u/b)}$ index was calculated by equation 5.

Rainfall and index trends

To examine the claim that a rising DDH/100mm index for two consecutive months is indicative of an impending feed shortage rainfall records for the three centres were examined to establish dry periods and their antecedent rainfall conditions. The rationale is that at constant stocking rate an upward trend in the index must be associated with a declining trend in the rolling 12-month rainfall totals. 'Dry periods' were defined as individual or consecutive months in which the 12-month moving rainfall total is less than the long term average. The rainfall trend at the start of each dry period was identified by the change in the rolling values for the two months before the start of the period. A downward trend would lead to an increase in the DDH/100mm index for two consecutive months at constant stocking rate.

Results and discussion

Carrying capacity benchmarks

The carrying capacity benchmarks for each location, together with the equivalent actual carrying capacities, were:

LOCATION	CARRYING CAPACITY. BENCHMARK DDH/100MM$_{(BM)}$	CARRYING CAPACITY DSE/HA
Bourke	56.91	0.55
Cobar	60.64	0.62
Broken Hill	55.31	0.38

While these values are considerably higher than might be realised on many properties, particularly on soils subject to woody shrub encroachment, they are not unreasonable for better quality land in good condition. The figure for Bourke, for example, is comparable with the value of 55.6 DDH/100mm calculated from the 'normal average stocking rate' figure provided by a grazier practicing cell grazing on alluvial floodplain soils in the adjacent Brewarrina district (average annual rainfall 385 mm; G Finlayson, pers. comm.)

Index behaviour – monthly stocking rate adjustment

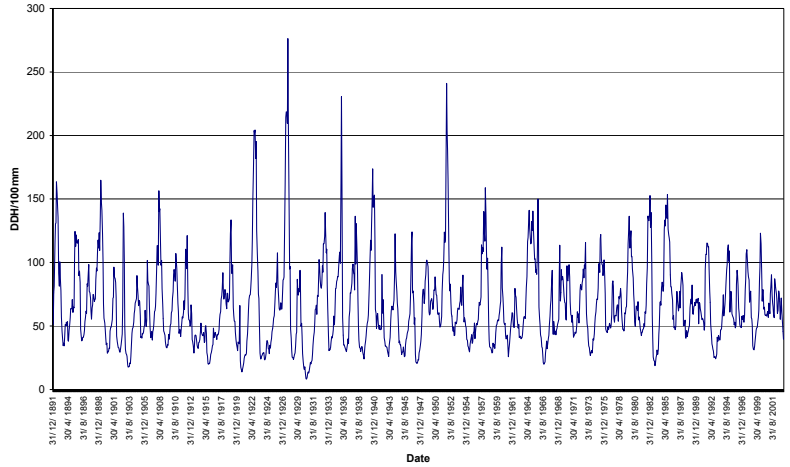
Figures 1 and 2 indicate that when stocking rate is adjusted monthly in an attempt to achieve proper utilisation of pasture growth, the values of the resulting index DDH/100mm$_{(u)}$ vary widely. For all locations, less than 20 % of observations fell within 10% of the carrying capacity benchmark and a small percentage of observations varied from the benchmark by over 100%.

Figures 3 and 4 present the equivalent data for DDH/100mm$_{(b)}$, representing a proper stocking regime in which the carrying capacity benchmark and rolling 12-monthly rainfall are used to calculate the stocking rate each month (SR_b). In this case the performance of the index is slightly better, with 20-25% of observations falling within 10% of the benchmark but extreme fluctuations still occur and again a small percentage of observations deviate from the benchmark by over 100% of its value.

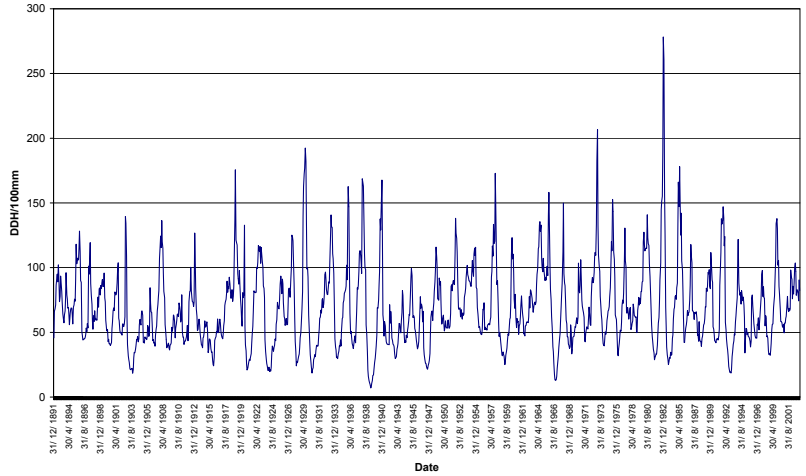
Since the stocking rate index bears little relationship to the carrying capacity benchmark even when stocking is adjusted to a theoretically 'proper' level such comparison can have no value, in practice, in indicating when stocking rate should be adjusted to match seasonal conditions.

Figure 1. Variation in the actual stocking rate index DDH/100mm$_{(u)}$ under a proper stocking regime based on pasture utilisation, 31/12/1891 to 31/3/2003.

(a) Bourke



(b) Cobar



(c) Broken Hill

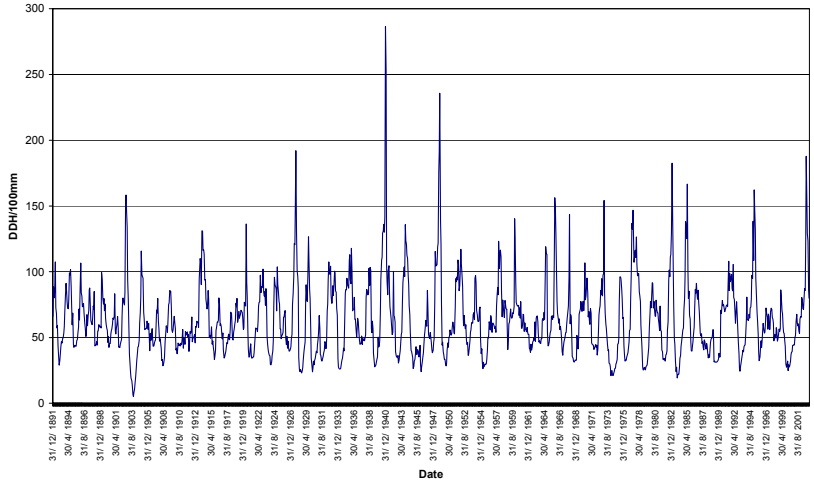
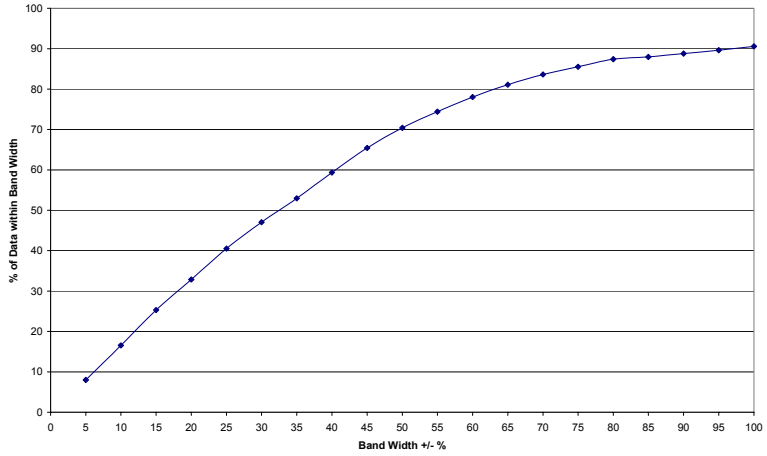
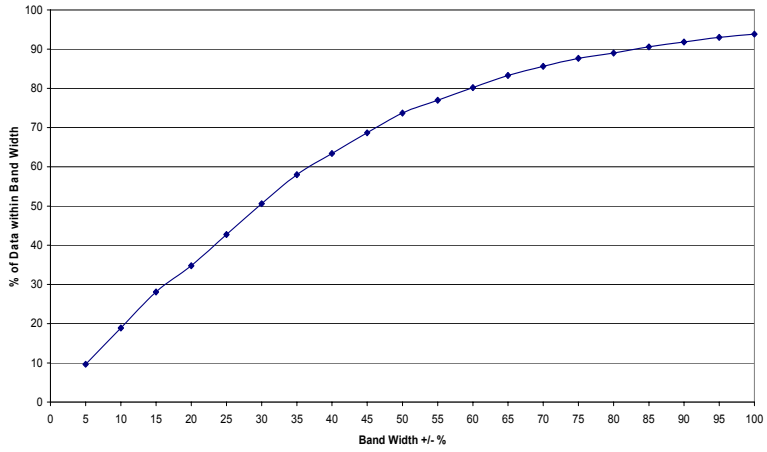


Figure 2. Variation in the actual stocking rate index DDH/100mm$_{(u)}$ in relation to the carrying capacity benchmark. Graphs indicate the % of the total number of monthly observations between 31/12/1891 to 31/3/2003 for which the value of the index was within the band width, centred on the carrying capacity benchmark, indicated on the x axis.

(a) Bourke



(b) Cobar



(c) Broken Hill

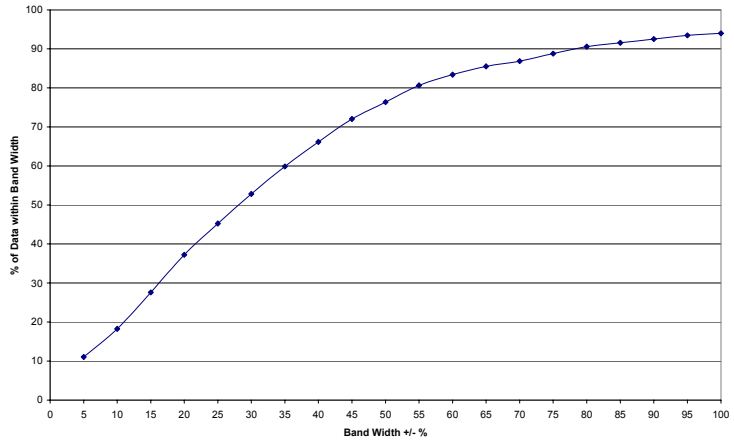
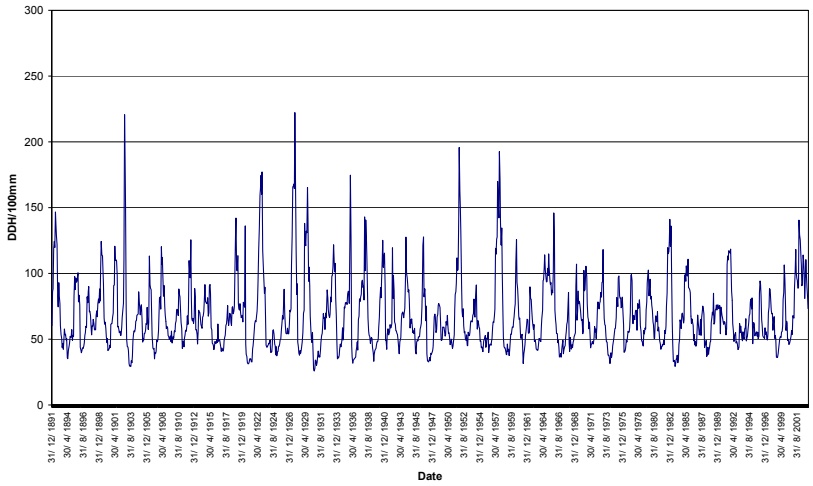
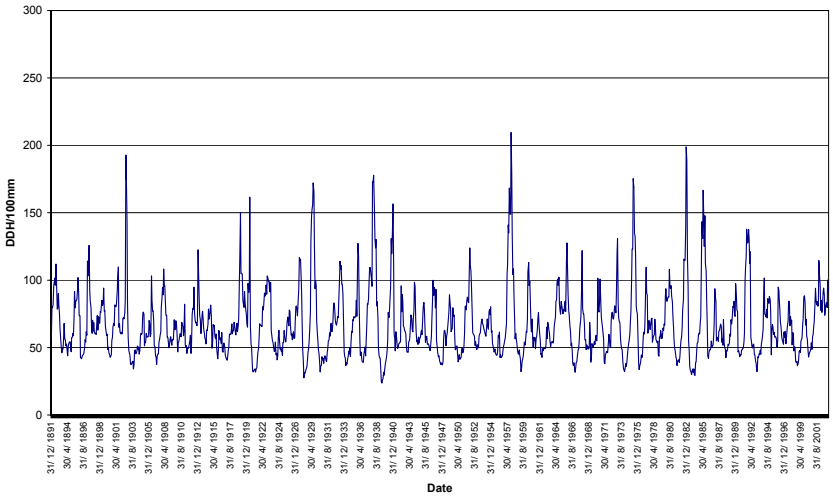


Figure 3. Variation in the actual stocking rate index DDH/100mm$_{(b)}$ under a proper stocking regime based on the carrying capacity benchmark and 12-monthly rainfall, 31/12/1891 to 31/3/2003.
(a) Bourke



(b) Cobar



(c) Broken Hill

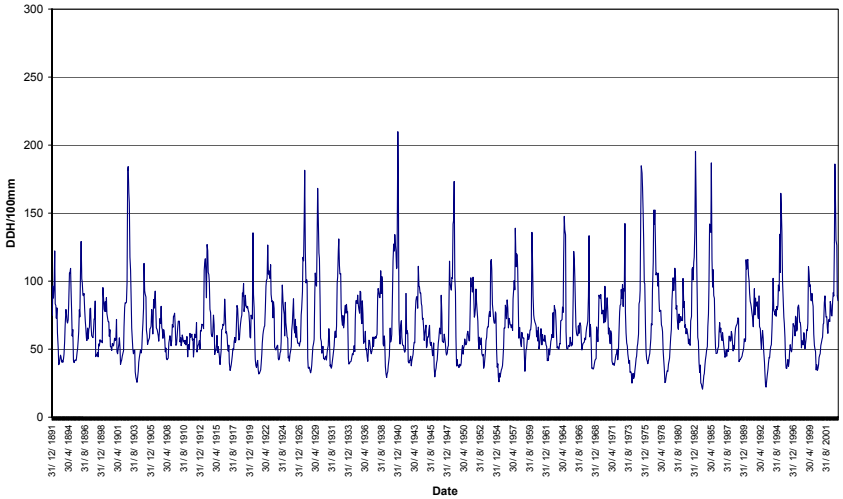
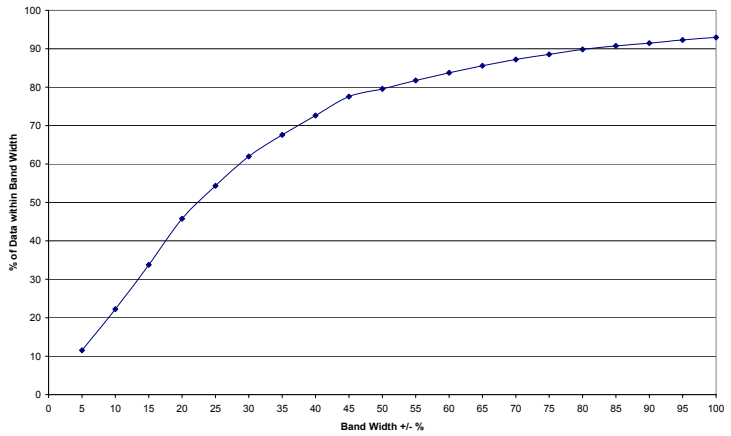
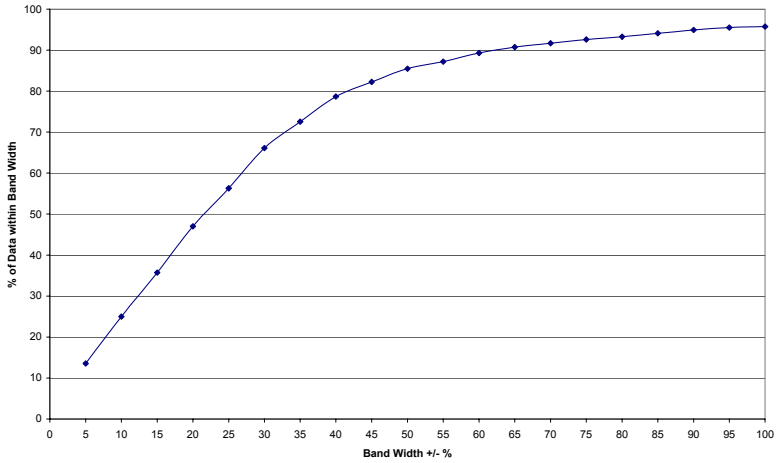


Figure 4. Variation in the actual stocking rate index DDH/100mm$_{(b)}$ in relation to the carrying capacity benchmark. Graphs indicate the % of the total number of monthly observations between 31/12/1891 to 31/3/2003 for which the value of the index was within the band width, centred on the carrying capacity benchmark, indicated on the x axis.

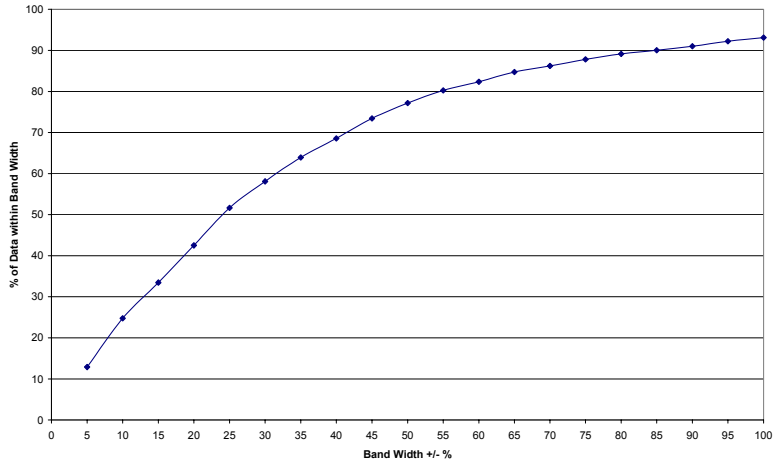
(a) Bourke



b) Cobar



(c) Broken Hill



Index behaviour with biannual stocking rate adjustment

Adjustment of stocking rate biannually reduced the percentage of observations occurring within 10% of the benchmark (Table 1). Despite its impracticality the monthly adjustment regime thus appears to provide a better theoretical basis for evaluation of the index .

Method SR calculation	Frequency of adjustment	Broken Hill	Cobar	Bourke
Utilisation	Monthly	18.2	18.9	16.5
	Biannual	16.4	16.5	14.7
Benchmark	Monthly	24.8	25.0	22.2
	Biannual	20.5	20.9	17.6

Table 1. Percentage of monthly values of DDH/100mm within ±10% of the benchmark

Periods of 'ideal' index behaviour

Despite the deficiencies of the index when applied over the long run of the historical record it is possible that individuals applying the index could find its behaviour conforms with expectations over shorter periods, perhaps accounting for the support that the index enjoys among some graziers.

Table 2 indicates that with biannual stocking rate adjustment, approximating a practical grazing regime, relatively long periods do occur in which the index conforms to expectations and remains within 10% of the benchmark. However, these periods are not so long that erratic behaviour would not be experienced within practical time frames.

Calculation method	Broken Hill	Cobar	Bourke
Utilisation	10	9	12
Benchmark	13	9	7

Table 2. Maximum length of time (months) for which the DDH/100mm index remained within ± 10% of the benchmark with biannual stocking rate adjustment.

Relationship between stocking rates calculated by alternative methods

Although DDH/100mm bears no relationship to the carrying capacity benchmark that could indicate that correct stocking has been achieved, or that stocking rate should be adjusted in line with seasonal conditions, the proper stocking rates SR_u and SR_b are more closely related. Figure 5 indicates the sequence of 'proper' stocking rates calculated by the two methods; the correlation between them is shown in Figure 6. For all locations the pattern of variation is similar although local peaks and troughs can differ considerably. For both Bourke and Cobar stocking rates calculated by the benchmark method tend to be conservative relative to the utilisation method while for Broken Hill the reverse is the case.

Nevertheless, there is sufficient correlation between the proper stocking rates calculated by the two methods to suggest that SR_b, which can be readily calculated from data available to pastoralists, might be a useful surrogate for the proper stocking rate SR_u determined from actual pasture growth. Another measure of this relationship is shown in Figure 7 in which the actual pasture utilisation realised by the two methods is plotted. This figure indicates that some calculated realised utilisation values are spurious (above 100%) but that within the range of utilisation levels that might be tolerated in practice, say 0-50%, the two methods produce very similar results. The spurious values produced by the calculations occur when rainfall or pasture growth in a 12 month window falls to very low levels. The example for Cobar (Figure 8) is typical of the relationship for all three locations. It indicates that realised utilisation gradually rises as 12-monthly rainfall declines, reaching very high or spurious

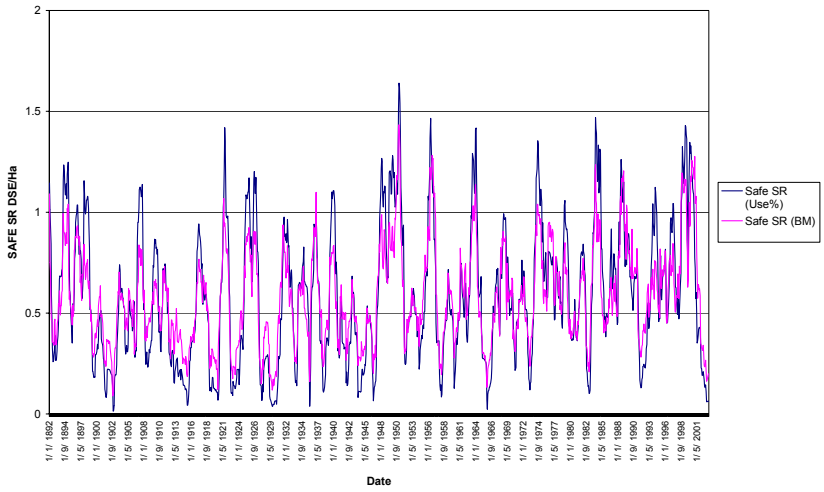
values as rainfall declines below approximately 150 mm. Realised utilisation levels ≤ 20%, compared with the desired theoretical value of 17.5%, are achieved for about 60% of observations, while utilisation ≤ 30%, a commonly used rule of thumb for sustainable grazing, is achieved for about 85% of observations.

The lag between the period used for determining stocking rate and the period for which it is applied thus inevitably leads to realised utilisation levels that may over- or under-shoot the theoretical target. Such effects are inevitable given the extreme variation in rainfall totals for moving 12-month windows (Figure 9). Such variation also ensures that even over short periods, the DDH/100mm index may fluctuate widely even at constant stocking rate. Continuous monitoring of the level of utilisation actually achieved is thus required, as advocated by both Bartle (2003) and Martyn (2005), but such monitoring becomes critical when rainfall is low in any 12 month period. Inspection of Figure 8a, and its counterparts for the other locations, suggests that the appropriate threshold is approximately 150 mm for Bourke and Cobar and 120 mm for Broken Hill. Application of the calculated proper stocking rates could result in levels of utilisation much greater than anticipated when rainfall in a 12 month period falls below these levels. To be alerted to such situations graziers would benefit from projecting the 12-month rainfall total 3-6 months ahead based on monthly medians (with arbitrary adjustment for seasonal climate forecasts when indicators such as the SOI Phase have useful skill). If rainfall is likely to fall below the threshold, application of the calculated stocking rate should be tempered by careful scrutiny of the levels of utilisation and ground cover observed in the field.

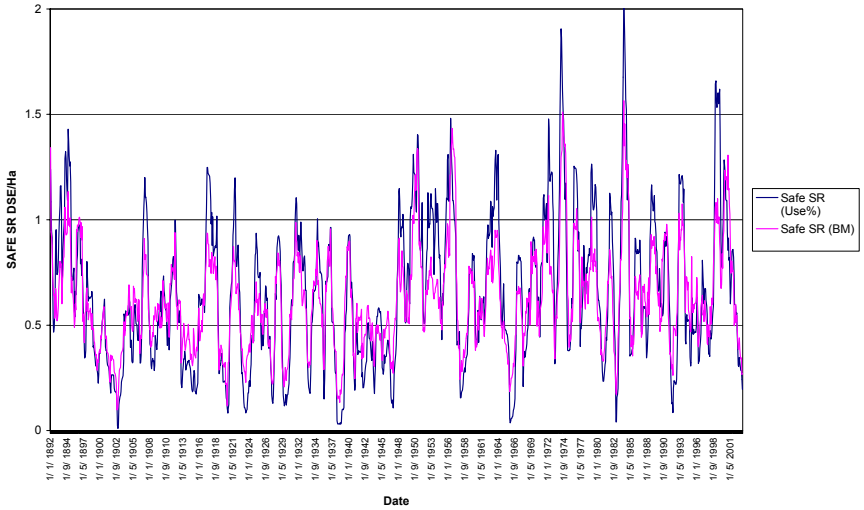
Although not of direct relevance to this study it is interesting to note that wide variation in 12-monthly rolling rainfall totals is characteristic even of environments with much more reliable rainfall that the pastoral zone. This variation is shown for Orange, NSW in Figure 10. Even in these environments the DDH/100mm index could be expected to behave in a manner similar to that reported above, and its behaviour in relation to a static benchmark is likely to be equally erratic.

Because SR_b fairly closely tracks SR_u, and results in similar levels of pasture utilisation, it provides a 'dynamic benchmark' which can be readily calculated and to which actual stocking rate may be compared. While comparison of actual DDH/100mm with the carrying capacity benchmark, $DDH/100mm_{(BM)}$, provides no signal that could be used to judge the appropriateness of current stocking rate (Figures 3 & 4) comparison of actual stocking rate (DSE/ha) with SR_b will provide such a signal and should be readily implemented by graziers provided a realistic estimate of carrying capacity is available.

Figure 5. Proper stocking rates, calculated monthly, based on pasture utilisation (SR_u) or 12-monthly rainfall (SR_b).
(a) Bourke



(b) Cobar



(c) Broken Hill

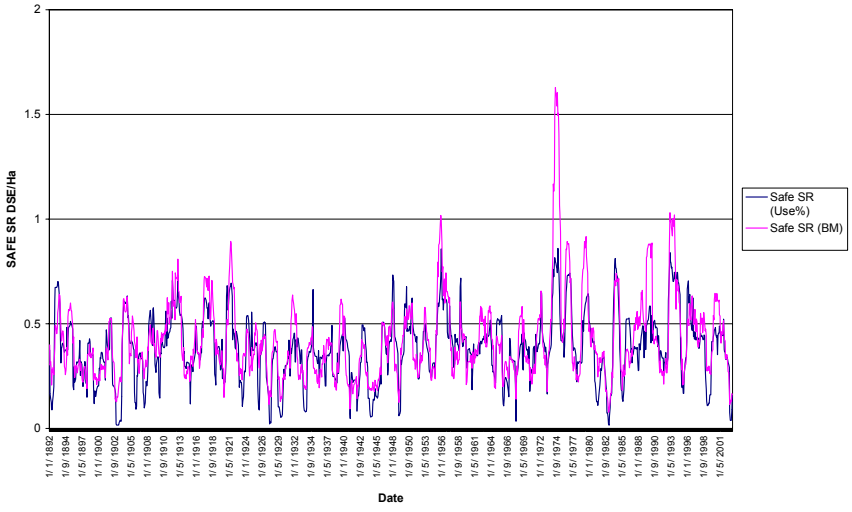
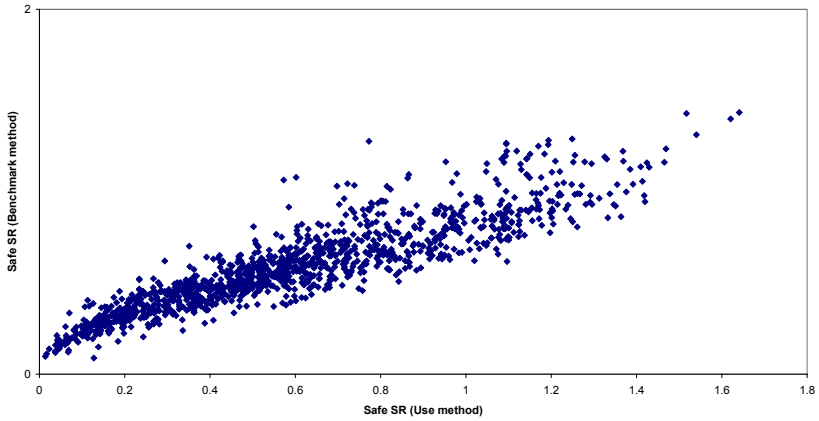
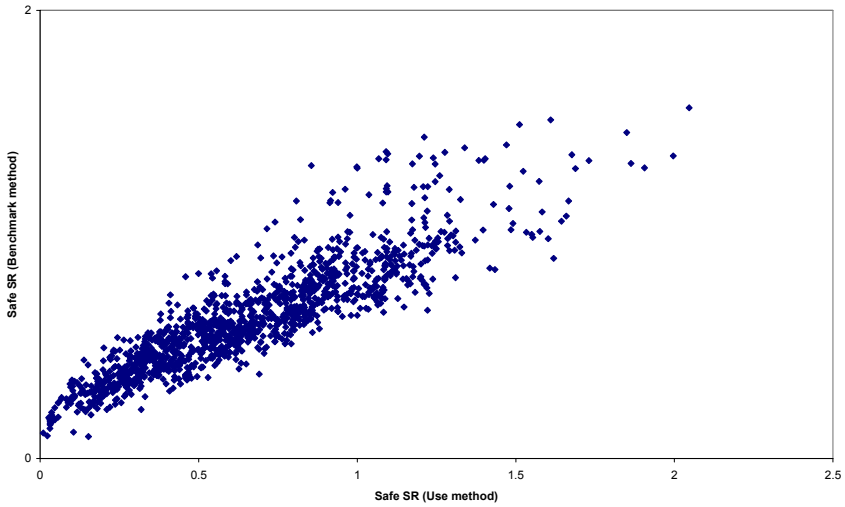


Figure 6. Relationship between proper stocking rates based on pasture utilisation (SR_u) and 12-monthly rainfall (SR_b).
(a) Bourke



(b) Cobar



(c) Broken Hill

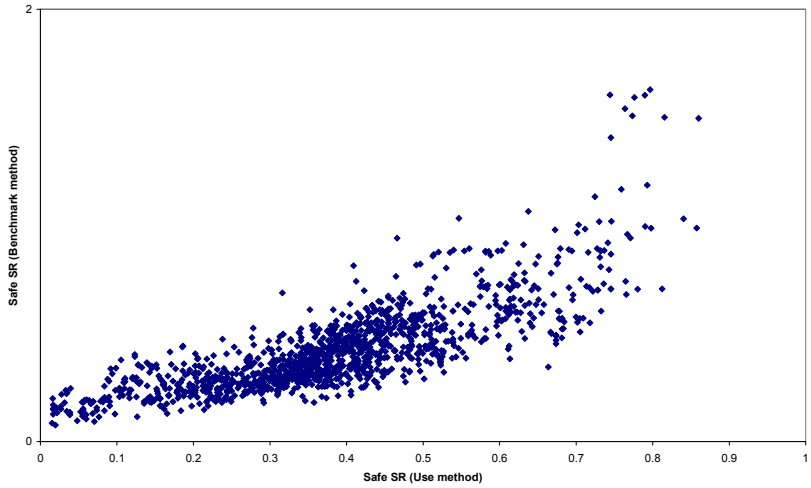
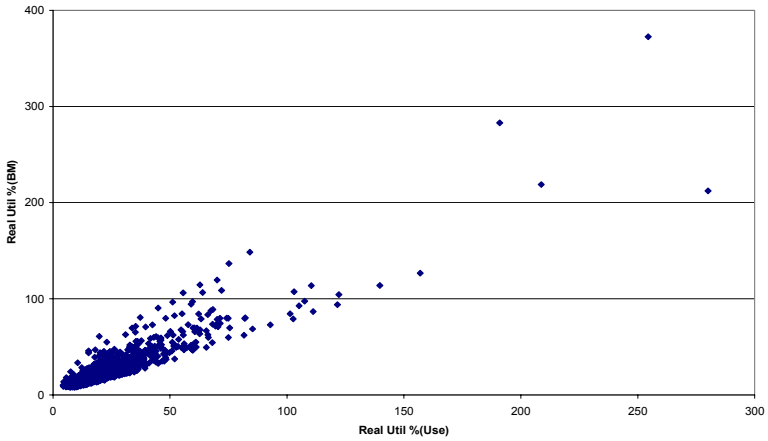
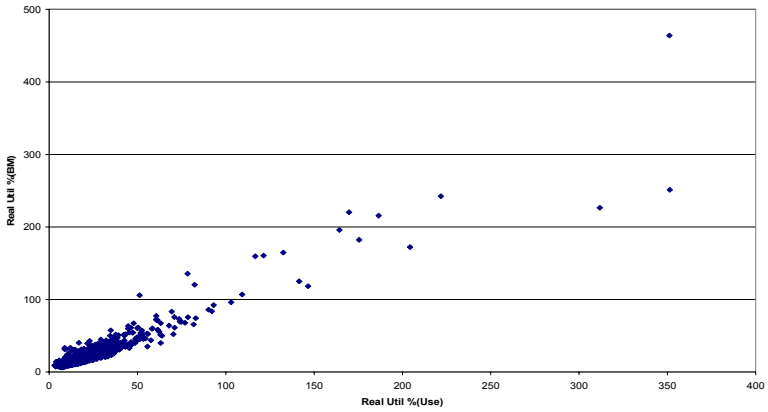


Figure 7. Relationship between realised utilisation (%) achieved by proper stocking rates based on pasture utilisation (SR_u) and 12-monthly rainfall (SR_b).
(a) Bourke



(b) Cobar



(c) Broken Hill

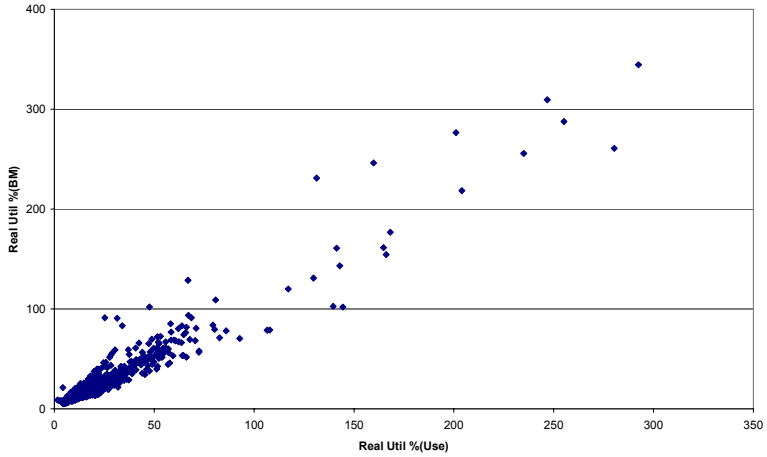
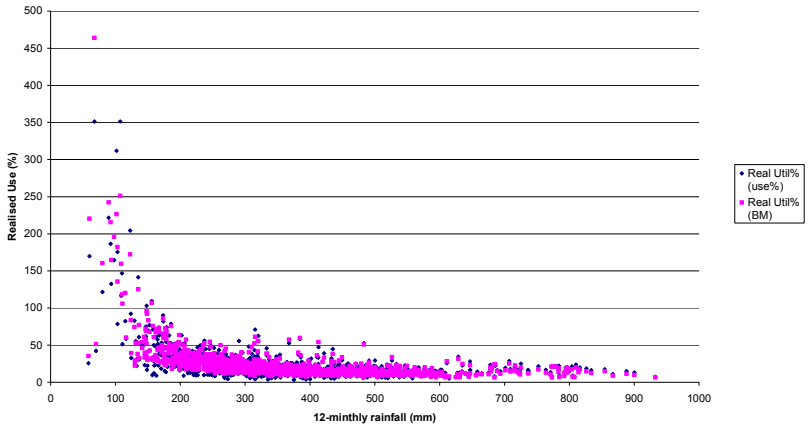
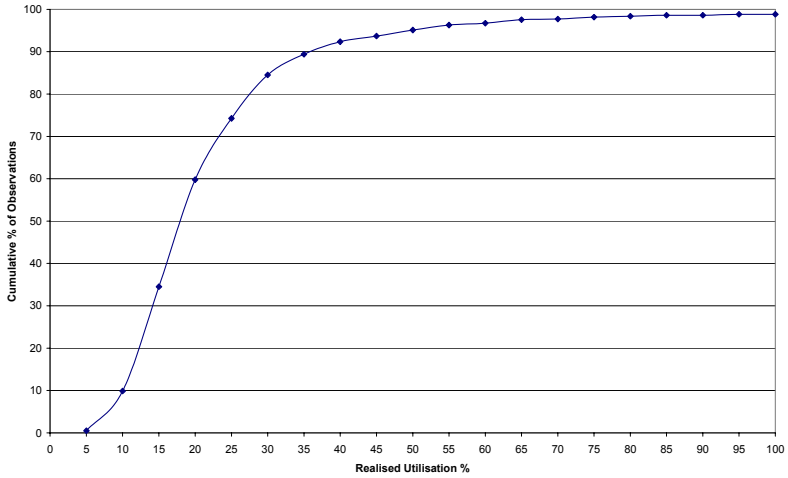


Figure 8. Realised utilisation for proper stocking rates determined by two methods at Cobar. (a) realised utilisation as a function of 12-monthly rainfall (b) cumulative frequency distribution of realised utilisation for SR_u (c) cumulative frequency distribution of realised utilisation for SR_b.
(a)



(b)



(c)

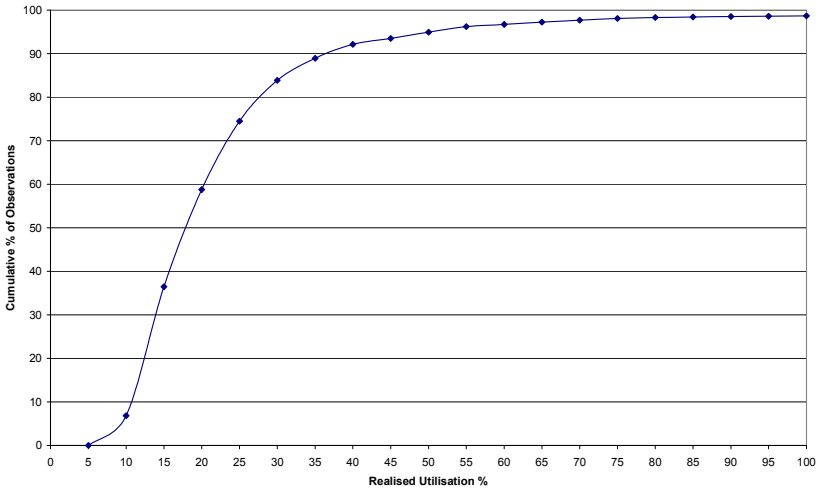
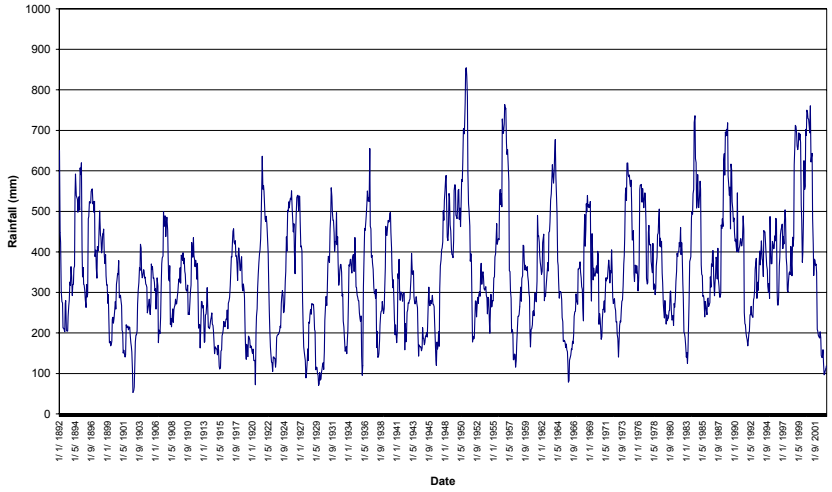
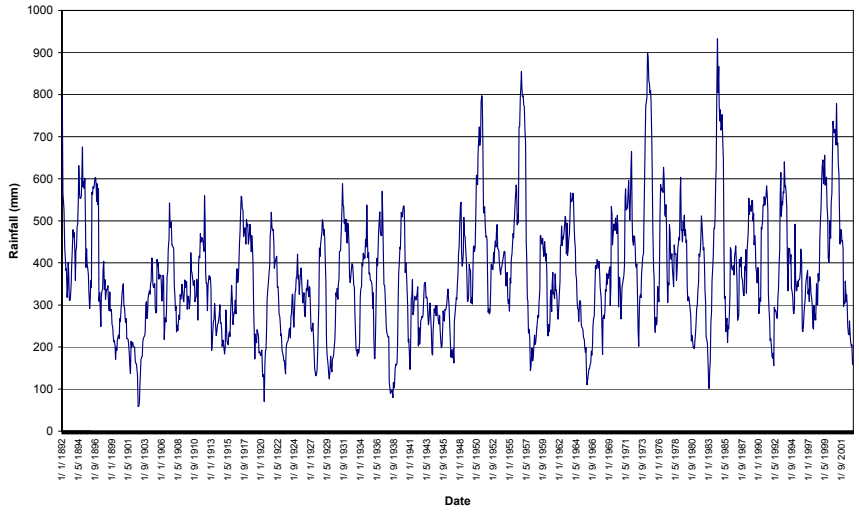


Figure 9. Total rainfall for moving 12-month periods at three locations.
(a) Bourke



(b) Cobar



(c) Broken Hill

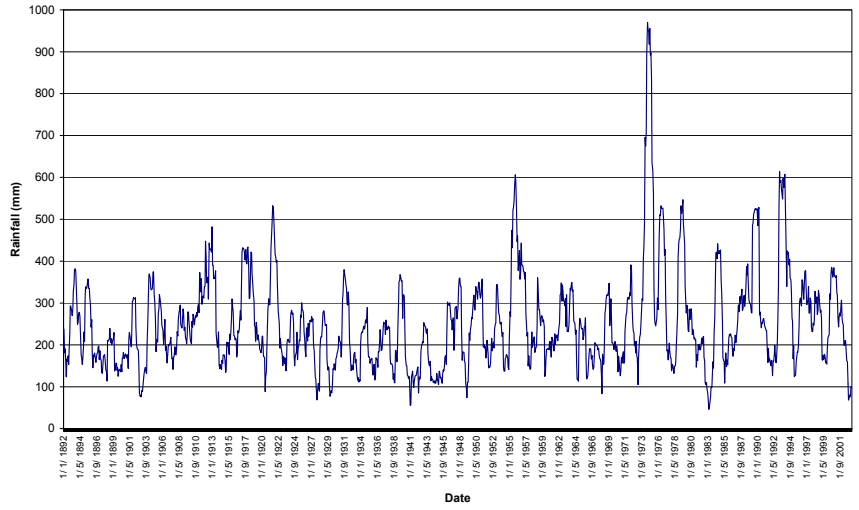
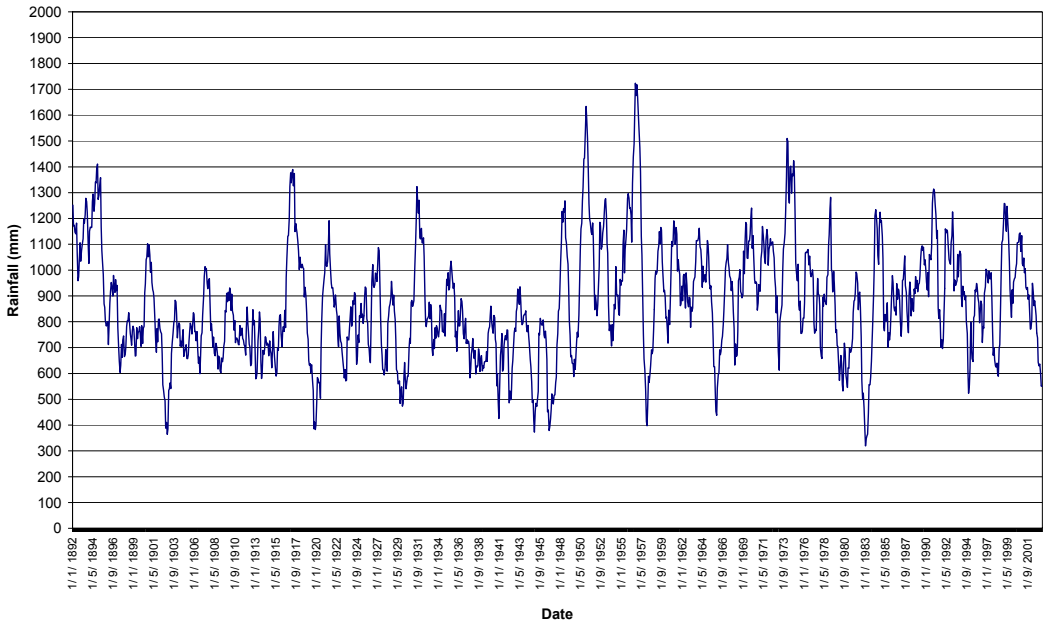


Figure 10. Variations in rolling 12-monthly rainfall totals from 31 December 1890 to 31 March 2003 for Orange, NSW (average annual rainfall 878 mm)



Stocking rate adjustment based on index trends

Although comparison of the DDH/100mm index with the carrying capacity benchmark provides no useful signal in terms of correct stocking, and could lead to serious errors in decision making, another claim for its utility rests on the assertion that continuous upward movement in the index for two consecutive months is indicative of an impending dry spell or feed shortage.

At constant stocking rate, such an upward trend would require a similar downward trend in the rolling 12-month rainfall totals. Table 3 indicates that such trends are nowhere indicative of long dry spells (>24 months). For shorter dry spells some shift from the null (50:50) probabilities associated with declining rainfall totals may exist but both spatial and temporal variations will prevent any general claim for the significance of such trends (and associated trends in the index) as predictors of future seasonal conditions.

Length of dry period (months)	Trend in rolling 12-monthly rainfall totals for the two months before the commencement of dry period					
	Broken Hill		Cobar		Bourke	
	Downward	Upward	Downward	Upward	Downward	Upward
≤ 6 months	16	7	21	24	15	8
7-12 months	6	1	10	3	4	4
13-24 months	13	5	5	4	13	2
>24 months	4	5	3	5	3	4

Table 3. Antecedent rainfall conditions for dry periods of various length, 31 December 1890 to 31 March 2003.

Summary:

Long term data for (simulated) daily pasture growth and moving 12-monthly rainfall totals were used to examine the performance of the DDH/100mm stocking rate indicator under theoretically ideal management for three locations in the Western Division of NSW. Stocking rate adjustments were

made either monthly or biannually. Under these 'ideal' conditions, monthly values of the index fluctuated widely around the carrying capacity benchmark. Comparison of index values with this benchmark should not be used, in practice, to assist stocking rate decisions.

However, proper stocking rates calculated by applying rolling 12-month rainfall totals to the carrying capacity benchmark were similar to those determined from pasture utilisation, and resulted in very similar levels of realised utilisation. The carrying capacity benchmark could thus be a useful tool if used to calculate proper stocking rates for comparison with actual stocking rate, essentially establishing a 'dynamic benchmark'.

Use of a dynamic benchmark would not replace the need for continuous monitoring of paddock utilisation levels, and other indicators, as the utilisation realised even by the 'proper' stocking rate sequence may greatly exceed sustainable levels under low rainfall conditions (12-monthly total of 120-150mm depending on location). To help avoid these situations, pastoralists would benefit by projecting the rolling 12-month rainfall total forward for 3-6 months, based on climatological data or seasonal climate forecasts, to assess whether they are approaching a situation in which stocking rate calculations could be misleading, and emphasis should be placed on pasture monitoring alone.

Analysis of trends in rainfall prior to dry spells, which will be associated with complimentary trends in the DDH/100mm index at constant stocking rate, suggest that they have no general significance as indicators of impending feed deficits.

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