AUSTRALIAN RANGELAND SOCIETY

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JULY 8, 1977

WORKING PAPERS

Western Australian
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CONTENTS

A COMPARISON OF THE LAND ACTS OF AUSTRALIA

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At the CSIRO Division of Land Resources Management, Deniliquin, a project to identify the impact of economic, administrative, and social influences on rangeland management has begun. This paper reports some initial observations from a comparison of the Land Acts relevant to arid Australia. The relevant Acts are:

- Crown Lands Ordinance 1931-1975, N.T.
- Land Acts 1936-1975, Qld.
- Land Act 1933, W.A.
- Pastoral Act 1936-1976, S.A.
- Western Lands Act 1901, N.S.W.

These Acts of Parliament set up five administrative bodies who are responsible for the administration of all Crown Land in arid Australia. Only 1% of the arid lands of Australia have been alienated and are no longer Crown Lands.

Table 1 indicates the nature of the administrative bodies.

All States have established related Boards, Committees and Courts to assist the main administrative body (see Table 2).

All States divide the area for which they are responsible into a number of administrative regions (see Fig. 1). Table 3 gives an indication of the average number of stations per region.

Stations in the arid zone lease land from the Crown. The many forms of lease available in each State are listed in Table 4. Some leases are subject to area restrictions and all are subject to rental assessment. The type of lease with the smallest maximum area in each State is listed in Table 5.

The effect of these different administrative systems on the land resource is being investigated. Fig. 2 indicates the number of stations that lie on either side of the borders of each State. The causes and effects of these differences have not been identified. Obviously a great deal of the cause can be attributed to periods of closer settlement.

There appears to be

- no significant difference between the Northern Territory, South Australia and Western Australia;
- a very significant difference between the Northern Territory and Queensland;
- a very significant difference between New South Wales and South Australia inside the dog fence;
- no significant difference between New South Wales and Queensland;
- a significant difference between the Central and Western Division of New South Wales.

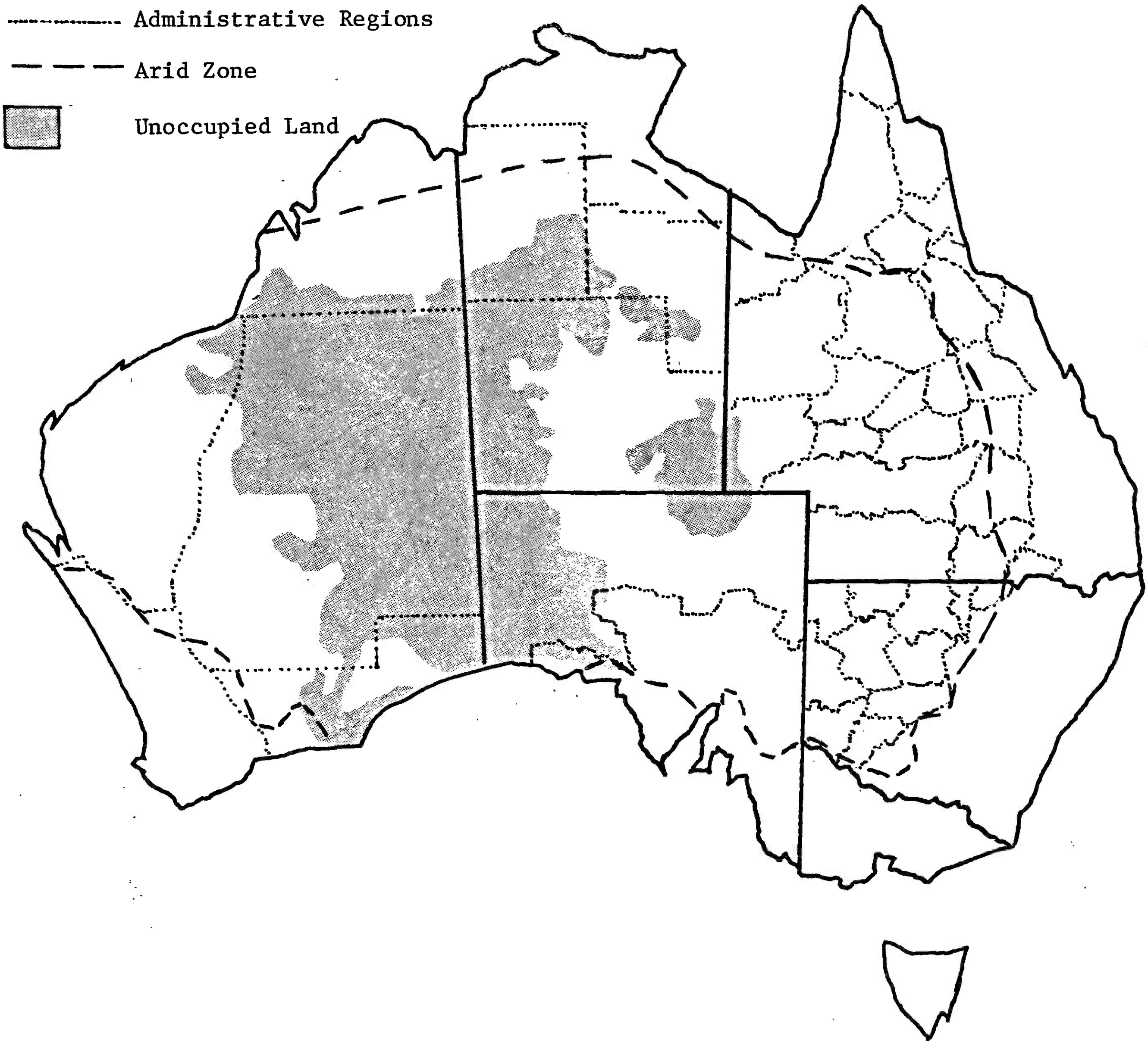

Fig. 1. Land Administrative Regions in the Arid Zone of Australia

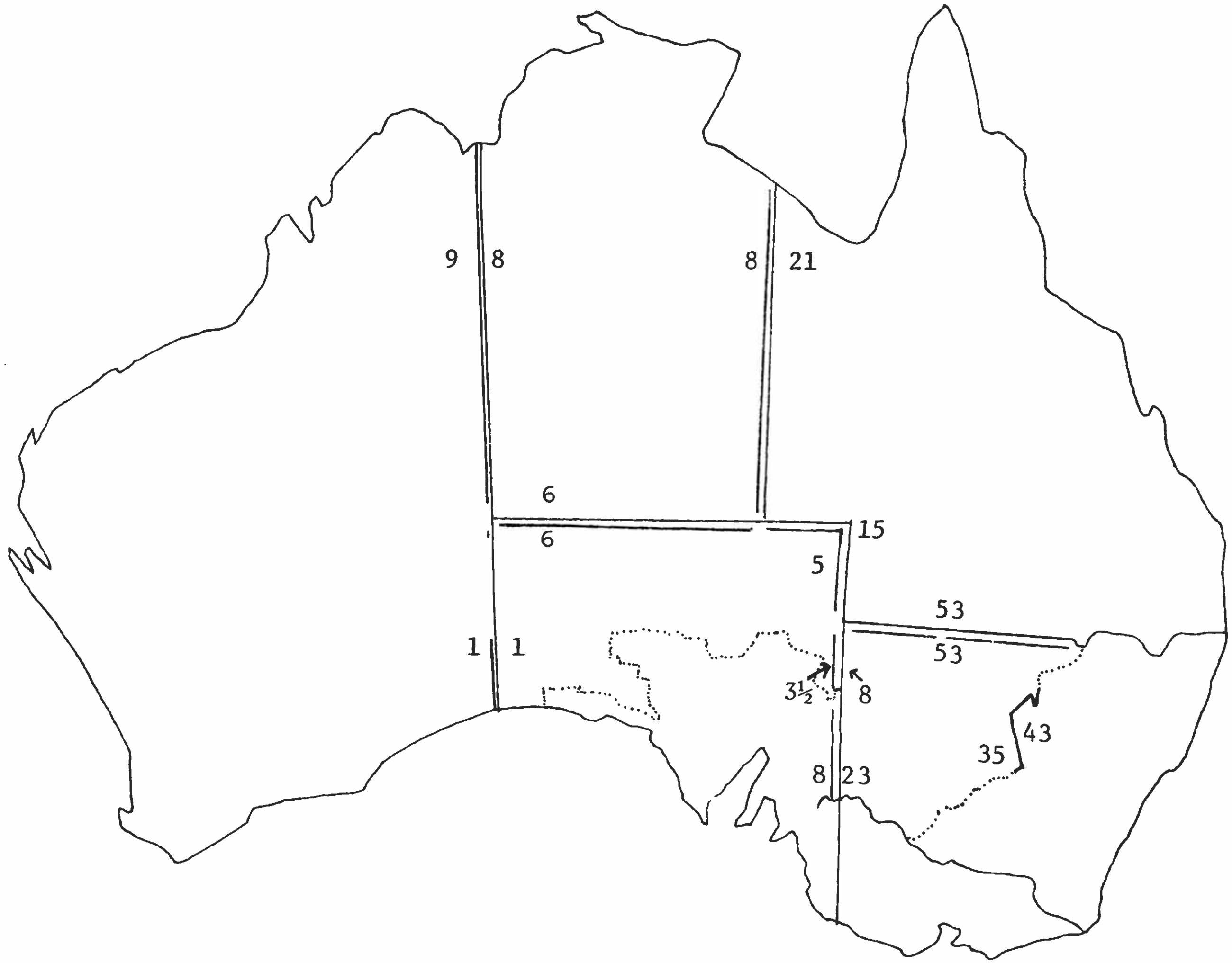

Fig. 2. Number of properties lying on administrative boundaries

Table 1. Administrative bodies responsible for arid Australia

State	Admin. body	Members of body	Qualifications of members	Quorum
N.S.W.	Western Lands Commission	Commissioner 2 Assistant Commissioners	Not specified " "	Refers most decisions to the local Land Board
N.T.	Land Board of the Northern Territory	Chairman Deputy Chairman 10 members	Not specified " " " "	Chairman or Deputy Chairman and 2 members
Qld.	Land Administration Commission	Chief Commissioner of Lands 2 others	Not specified " "	N.A.
W.A.	Department of Lands and Survey	Minister for Lands Under Secretary for Lands Surveyor General Other officers appointed from time to time	Not specified " " " " " "	Refers decisions to Pastoral Appraisement Board
S.A.	The Pastoral Board	Chairman 2 others Governor may appoint a fourth from time to time	At least one member must have been actively engated in the pastoral industry	Any 2 members

Table 2. Boards, Committees and Courts to assist the main administrative body

State	Sub-body	Members of body	Qualifications	Size of quorum	Retirement age	Appointment term
N.S.W.	Local Land Board (one for every admin. district or several districts)	Assistant Commissioner and 2 others appointed by Minister	Not specified	Chairman and 1 other	Assist.Comm. 65 yrs. Appointed member 70 yrs.	†
	Appeal from above goes to:					
	Land and Valuation Court	† (often has 2 judges)	†	†	†	†
N.T.	No sub-body to Land Board	N.A.	N.A.	N.A.	N.A.	N.A.
Qld.	Committee of Review (Grazing Selections only)	Member of Land Commission or Officer of the Dept. Lands and 2 others (not public servants)	Not specified Pastoral experience in region under review	3	Not specified	
	Land Court	Not more than 6 members	President must be barrister or solicitor of at least 5 years standing	1 member may sit on his own for certain matters	70 yrs	15 yrs
	Land Appeal Court	Judge of Supreme Court and 2 members of Land Court excluding member who gave the decision in the Land Court	†	†	†	†
W.A.	Pastoral Appraisement Board	Surveyor General (Chairman) Director of Agriculture 2 others appointed by Governor		Any 3	†	† † 5 yrs

Table 2 (continued)

S.A.	Tenants Relief Board	Judge of the Supreme Court, to be nominated by the Governor. 2 assessors, 1 nominated by the Minister, the other by the lessee	N.A.	N.A.

† Specified in another Act

Table 3. Number of stations per administrative region

	N.T.	N.S.W.	Qld.	S.A.	W.A.
Number of stations[a]	135	2,500	4,370	400	630
Number of regions	3	11	14	2	4
Average number of stations per region	45	230	310	200	160

a. Estimates only

Table 4. Lease titles, term, rental reassessment period, and maximum size

State	Lease title	Sub-title	Period of lease	Frequency of rental reassessment	Maximum size
N.S.W.	Western Lands Lease	Pref. Occupation Licence	40 years or perpetuity	10 years[a]	Leases in perpetuity have a limit of 2 home maintenance areas
		Occupation Licence	" " " "	" "	
		Permissive Occupancy	" " " "	" "	"
		Special Lease	" " " "	" "	"
		Annual Lease	1 year	N.A.	N.A.
		Stud Lease	40 years or perpetuity	10 years[a]	4 home maintenance areas
N.T.	Pastoral Lease		50 years (Max.)	10 years	12,949,760 ha (5,000 m^2)
	Agricultural Lease		Perpetuity	10 years	20,230 ha
	Grazing Licence		1 year	N.A.	N.A.
Qld.	Pastoral Lease	Pastoral Holding	30 years (Max.)	10 years	No restriction
		Pastoral Development Holding	30 years[b]	" "	" "
		Preferential Past. Holding	30 years (Max.)	" "	250 km^2
	Grazing Selection	Grazing Homestead Lease	30 years (Max.)	" "	18,250 ha[c]
		Grazing Farm Lease	" " "	" "	18,250 ha[d]
	Stud Lease		40 years (Max.)	" "	3 living areas
	Occupation Licence		Renewed yearly	N.A.	Dependent on lease type
	Grazing Homestead Perp. Lease		Perpetuity	10 years	18,250 ha[c]
	Grazing Homestead Freeholding Lease		40 years[e]	N.A.	18,250 ha[c]

Table 4 (continued)

W.A.	Pastoral Lease		Leases expire either on 31.12.1982 or 30.6.2015	15 years 10 years	404,686 ha (1 million ac.) " "
S.A.	Pastoral Lease	Leases granted after 12.12.1929 North or West of the Murray River	42 years	21 years or 7 years[f]	No restriction No restriction
		Leases granted after 12.12.1929 North or West of the Murray River not likely to be required for closer settlement	42 years	21 years or 7 years[f]	No restriction No restriction
		Leases granted after 12.12.1929 North or West of the Murray River likely to be required for closer settlement	21 years	21 years or 7 years[f]	No restriction No restriction
		Leases North or West of the Murray River granted after 1939 which have not been previously leased	21 years	21 years or 7 years[f]	No restriction No restriction
		Leases North or West of the Murray River which include land which has been previously leased	42 years	21 years or 7 years[f]	No restriction No restriction
		Leases granted for the purpose of Closer Settlement	To be fixed - maybe 21 years	21 years or 7 years[f]	10,000 sheep

a. Where the lease has less than 20 years to run the assessment period is the remainder of the lease.
b. Pastoral Development Holdings have a maximum term of 50 years, but only extensive development conditions justify a term of more than 30 years.
c. When the Commissioner feels that 18,250 ha does not constitute a living area, up to 24,300 ha may be granted.
d. Grazing farm leases are only granted when the area does not constitute a living area.
e. At the end of 40 years the lessee obtains a title in fee simple (freehold) to the lease, subject to the condition that it may not be sold to a corporation.
f. All leases granted after 1960 have a rental reassessment period of 7 years.

Table 5. Lease type with smallest maximum area in each State

	Maximum area	Minimum area
New South Wales - Western Lands Lease	2 Home Maintenance Areas	-
Northern Territory - Pastoral Lease	12,949,760 hectares	-
Queensland - Grazing Selection	18,500 hectares - 24,300 hectares if area not greatly in excess of 1 Home Maintenance Area	-
South Australia - Pastoral Lease	-	-
Western Australia - Pastoral Lease	404,686 hectares	6,000 sheep or 1,200 cattle

EFFECTIVE CONTROL: THE NEED FOR LESS SEVERE PENALTIES

M. D. Young

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Abstract

At present the only penalty that land administrators may use in managing a lease is forfeiture. There is a need for administrators to be able to use less severe penalties. A system of fines is suggested.

Introduction

Five States in Australia contain arid Crown Land which is available for lease, subject to the condition that the carrying capacity of the lease is maintained. In all States, the penalty for not complying with this condition is forfeiture. This very severe penalty has never been imposed. However, there have been several instances where it has been suggested to a lessee that his lease would be forfeited, unless he reduced his stock numbers. In some of these cases the lessees have responded by reducing their stock numbers.

Threat of forfeiture is a powerful tool in land management. However, it is difficult to carry such a threat to its conclusion. If an administrator did forfeit a lease, he may precipitate a political crisis. Appeals would be made to the various members of parliament and it is likely that the decision would be reversed. If it were not reversed the pastoral houses, which finance much of the pastoral zone's production, may restrict further credit to pastoral lessees. They would not, and could not, be expected to finance any lease which may be forfeited. When a lease is forfeited a lessee's creditors may lose the capital they have invested in the lease.

To avoid this situation there is a need for a less severe penalty system associated with a pastoral lease's conditions. A system which shows promise is the use of fines. Fines are already used in some sections of the relevant Land Acts to prevent people from holding too great an area of land, making incorrect declarations, not paying rents, etc.

The Pastoralist's Perception of the Problem

Generally a pastoralist is encouraged to obtain the maximum amount of liberty he wants within the bounds set by the land administrator. Society encourages him to strive to maximize his welfare. At any one point in time

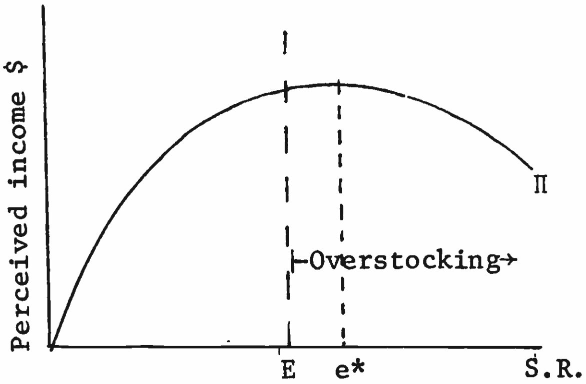

Fig.1 Overstocking likely

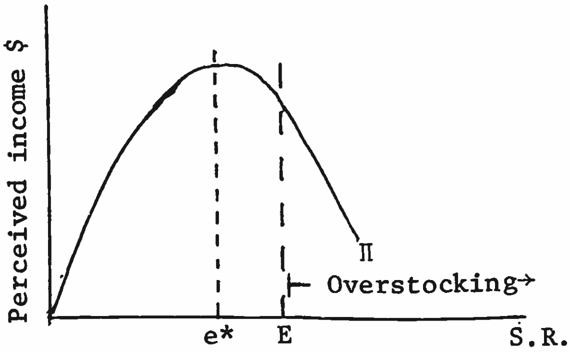

Fig.2 Overstocking unlikely

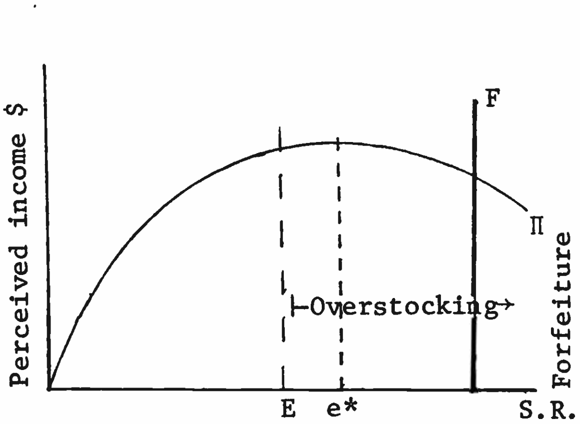

Fig.3 Current cost of being caught

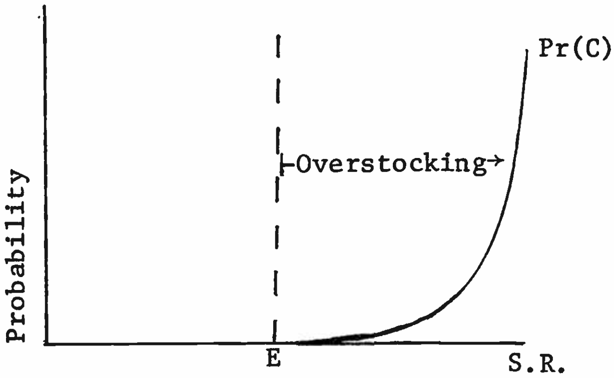

Fig.4 Current probability of being caught

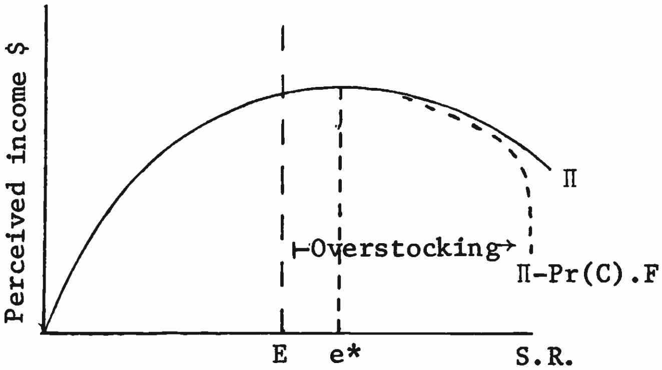

Fig.5 Current situation

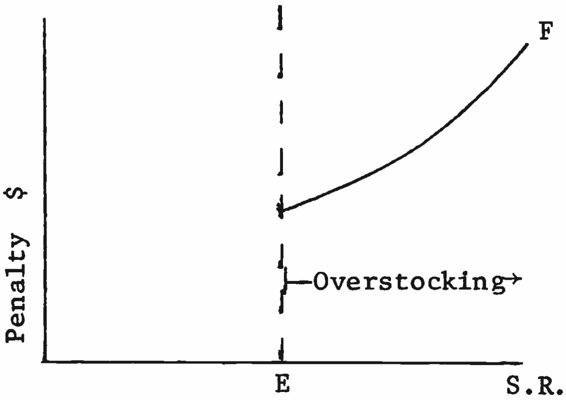

Fig.6 Recommended penalty

Π = Income
Pr (C) = Probability of being caught
F = Penalty or fine
S.R. = Stocking rate

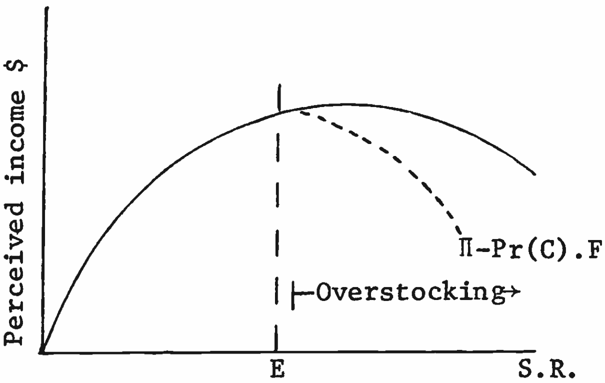

Fig.7 Recommended situation

a pastoralist has a conception of the income he can earn at various stocking rates. Linked closely to this concept of potential income is his perception of the probability of obtaining these levels of production. This situation can be represented by an income curve (see Fig. 1). The perceived optimum stocking rate which maximises income is indicated by e^*. There is also a maximum rate of extraction commensurate with maintaining the productive potential of the lease, E.

If the optimum rate of extraction, e^*, is less than E, there is no need for administrators to regulate a pastoralist's stocking rate (see Fig. 2). Unfortunately this does not always appear to be the case. Often managers perceive that the optimum rate of extraction, e^*, is greater than the safe rate of extraction, E, (see Fig. 1).

The present legislation implies that pastoralists should not stock at an intensity which is greater than E. There is a need to find effective legislation which will prevent pastoralists from extracting too much from the land resource.

It is the perceived cost of being caught which prevents overgrazing. The cost of being caught depends upon the probability of being caught and the penalty which results from being caught. Land administrators could introduce legislation which would make it optimal to stock at rates less than E. This can be done by increasing the probability of being caught or the cost of being caught.

The probability of being caught is determined by the frequency and accuracy of inspections by pastoral inspectors, the reliability of stocking rate returns submitted by pastoralists and perhaps, in the future, by some form of remote sensing. At present the probability of being caught for minor offences is very low (see Fig. 4). Stock cannot be counted and the condition of a station is hard to assess quickly. The frequency of assessment depends upon the State. Stock returns can only be checked roughly from wool returns and livestock sale notices. Until the vegetation of a station reveals that a station is overstocked or the manager tells someone he is overstocked the probability that he will be caught is low. Using the available techniques of range assessment the cost of increasing the probability of being caught is astronomical and it would be more fruitful to increase the cost of being caught.

If the current probability of being caught is combined with the fine which results from being caught, we observe that present regulations are not very effective in achieving their objectives (see Fig. 5). Under current legislation a station manager may perceive that it is optimal for him to exploit his station. To obtain better control it is possible to either modify the legislation to enable the cost and risk of being caught to increase or to increase the probability of being caught. A system of fines which are related to the severity of the offence would achieve this modification (see Fig. 6). Pastoralists would respond to such a situation by reassessing the cost of and probability of being caught.

A system of fines which is related to the severity of the offence has the advantage that it produces revenue, while increasing the probability of being caught places extra demands on the finances available to administrators. The use of a fine system would also increase a pastoralist's perception of the probability of being caught.

Finally, there are difficulties in assessing the carrying capacity of a station as today people perceive a station's carrying capacity to be dependent upon recent climatic events. Carrying capacity is a dynamic variable. It may be advantageous to require lessees to maintain the condition of their stations, that is the long term productive potential of the station rather than the continually changing carrying capacity.

THE PSYCHOLOGY OF ARID ZONE MANAGEMENT

(The relationship between a manager's needs and the standard of resource management he adopts)

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Abstract

Using principles established by Maslow the relationship between a manager's needs and the stocking strategy he adopts is explored. Conclusions from economic and social surveys of the arid zone of Australia are then used to predict the likely effect of the socio-economic status of arid zone managers on the land resource. These predictions are related to some sections of Land Acts relevant to arid Australia.

Introduction

In the rangelands of Australia some land administrators are trying to influence the stocking strategies adopted by pastoralists, but in the final analysis it is always pastoralists who determine stocking pressure, it is they who determine the pressures which are placed on the land resource. They determine this pressure on the land by considering the pressures placed on them by their family, their friends, their administrators, their stock agents, their bank managers and many other people with whom they make regular contact.

As pastoralists increase the pressure on the land resource it is possible for overgrazing to occur.

Overgrazing occurs when the demands placed on a plant community are greater than it can sustain without decreasing future production. It is usually characterized by soil erosion, a decreasing population of perennial plants and an increasing population of annual plants. Soil erosion removes plant nutrients from the soil and hence decreases plant production. In the uncertain climate of the arid zone a predominantly annual plant community produces less animal produce than a perennial one. Thus overgrazing may lead to a decrease in future production - a decrease in the future carrying capacity of the land. Why do some pastoralists place extreme pressure on their land?

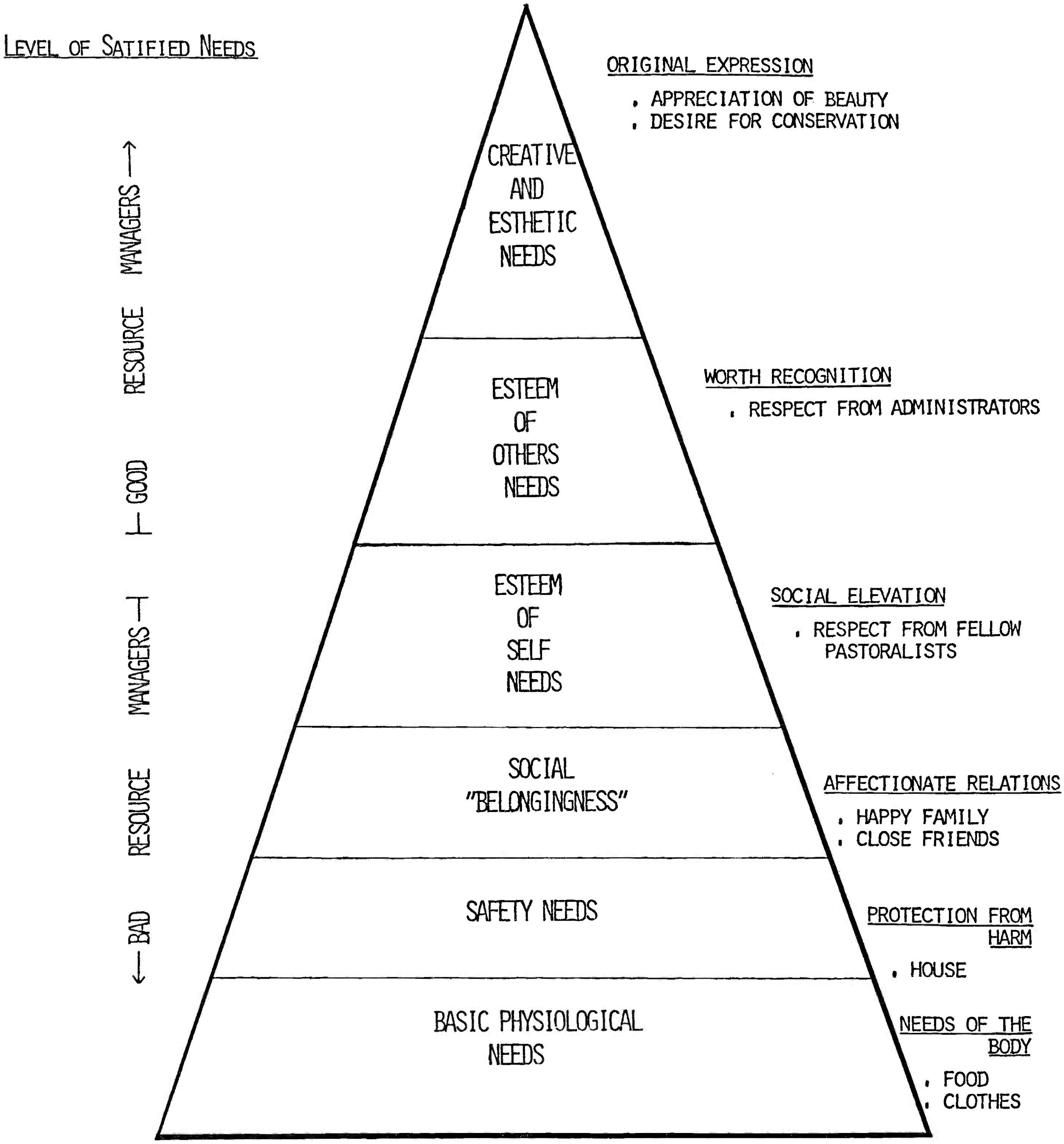
LEVEL OF SATIFIED NEEDS
BAD ⊥ GOOD
RESOURCE MANAGERS
RESOURCE MANAGERS
CREATIVE AND ESTHETIC NEEDS
ESTEEM OF OTHERS NEEDS
ESTEEM OF SELF NEEDS
SOCIAL "BELONGINGNESS"
SAFETY NEEDS
BASIC PHYSIOLOGICAL NEEDS
ORIGINAL EXPRESSION
. APPRECIATION OF BEAUTY
. DESIRE FOR CONSERVATION
WORTH RECOGNITION
. RESPECT FROM ADMINISTRATORS
SOCIAL ELEVATION
. RESPECT FROM FELLOW PASTORALISTS
AFFECTIONATE RELATIONS
. HAPPY FAMILY
. CLOSE FRIENDS
PROTECTION FROM HARM
. HOUSE
NEEDS OF THE BODY
. FOOD
. CLOTHES

Fig. 1

They do this because, either

a) they are natural gamblers; they realize that the pay-offs from carrying many sheep in good seasons are great and they are prepared to face the consequences of a bad season; they hope they can take sufficient evasive action to avoid severe damage to their land;

b) they are unaware of the damage they may cause by overgrazing; their perception of the biological resilience of their land is incorrect;

c) the social and economic pressures placed on them leave them no alternative but to place extreme pressure on their land.

We will ignore the gambler and the grazier who has a bad perception of his environment. These are better treated as separate topics. The aim of this paper is to attempt to address the problem of the third type of overgrazer from a psychological perspective.

Perhaps the first question which can be asked is what are the motivations or needs of a pastoralist who applies considerable pressure to his land and how do these needs contrast with those of the conservative manager? In the absence of any empirical data we will use Maslow's (1970) hierarchy of needs to attempt to identify *one type* of overgrazer.

A Manager's Needs

Maslow, in a general personality theory, analyses people's needs in terms of an hierarchical structure (see Fig. 1).

The lowest needs are *physiological* needs (food, water, warmth, etc.). These are followed by *safety* needs (job, security, shelter, etc.), then *belongingness and love* needs (family, etc.) and finally *esteem* (or community recognition and cultural) needs. Generally lower needs must be satisfied before higher needs become important to the individual. Maslow suggests that we only pay attention to our higher needs after our lower needs have been gratified.

It can be assumed, in Australia, that the physiological needs of all pastoralists are satisfied. We are not aware of any pastoralists who are not adequately clothed and fed. Thus we will not discuss this level of poverty any further.

At the next level, however, it is clear that not all pastoralists have their safety needs satisfied. A survey of rural poor in New South Wales found that "many respondents were in overcrowded substandard houses without adequate insulation, floor coverings and so on" (Commission of Inquiry into Poverty, 1974). Properties with poor economic returns and high debt clearly have less security than profitable enterprises. They are more concerned with short term survival than the long term consequences of overgrazing.

Poor financial circumstances also threaten belongingness and love needs in the context of the social isolation of the arid zone. For example, education costs are high because of the necessity to send children to boarding school. Parents with poor economic returns, therefore, obviously have more difficulty in providing such education than those in better financial circumstances. There is tremendous pride in being able to educate one's children. It enables the parents to belong to a community, to be respected by one's neighbours. Some may overgraze to maintain their position in society. By doing this they may be able to temporarily maintain their position in society.

Finally, esteem and cultural needs are satisfied from regular community activities such as involvement of the local pastoral associations or other community organizations. Obviously, the economic "battler" with no work force, and no spare time or cash can expect little involvement with such activities even if he is interested.

It seems that so far we have merely stated the obvious, graziers with more money are likely to satisfy higher needs than those with less income. Nevertheless, despite this assertion, Gibbings and Reithmuller (1976) report that "low levels of economic performance did not lead to an unfavourable attitude towards rural life, nor was it linked with dissatisfaction with goal achievement" in south-west Queensland woolgrowers.

We will argue, however, that although a general acceptance of arid zone living is common to all economic levels *overgrazing is more common among the poorer than better financially endowed graziers.* This is because a poor pastoralist has not consistently fulfilled either his security or belongingness needs; his aims are satisfied by short term practices which avoid the disaster of bankruptcy. This leads to the use of management procedures which tend to provide the most funds in the shortest time; for example overgrazing.

By contrast the high income grazier, having satisfied his lower needs, has the opportunity to assume more complex challenges such as gaining social prestige and the intellectual fulfilment which can be obtained by maintaining a well-regarded conservatively managed property. He will take an extension officer's advice because he has both the appropriate motivation and the economic leeway to do so.

While the management behaviour of these two types of pastoralists is quite different, both can be reasonably satisfied with their achievements (Gibbings and Reithmuller, 1976) because they have *different* aspirations.

Maslow (1970) develops 16 principles associated with the distinction between higher and lower needs, 4 of which will help elucidate the relevance of the hierarchy of needs to overgrazing.

1. *"The higher the need the less imperative it is for sheer survival, the longer gratification can be postponed and the easier it is for the need to disappear permanently."*

Conservative management may be regarded as a higher need; it is a dispensible luxury when compared with the pastoralist's need to survive a financial crisis. The benefits of conservative management are subtle and generally long term and are therefore not perceived as important in coping with an immediate security problem. Higher needs are less urgent than lower needs. It is easy to put off the gratification or fulfilment of higher needs. Unfortunately, conservative management is a higher need. A manager may feel justified in placing greater value on sending his son to boarding school than on having a station for him to return to. Educational costs are high and it is necessary to build these costs into a station's overheads (Yates, 1974). The alternative is to send one's children to a local school or educate them by correspondence. Apart from the argument that the quality of the education is less, there is certainly less esteem in these alternatives.

2. *"Living at the higher need level means greater biological efficiency, greater longevity, less disease, better sleep, appetite, etc."*

According to Maslow those able to operate at a higher need level are more effective both biologically and psychologically. Managers living at a lower level, therefore, may be less able to "rationally" consider alternative stocking strategies. Since their decisions are biased by short-term day-to-day survival they are inflexible in relation to their management decisions.

This inflexibility of lower need farmers can be a serious disadvantage. Gibbings and Reithmuller's (1976) study of the economic performance of Western Queensland graziers found flexibility to be a very important component of managerial success in the arid zone.

3. *"Higher needs require better outside conditions to make them possible."*

Good environmental conditions (e.g. social, familial, economic, educational) encourage the achievement of higher needs, or in this particular discussion, conservative management.

So far we have discussed only economic considerations, but it is also pertinent that arid zone pastoralists often operate under conditions of extreme social isolation which has at least three important consequences:

(i) social recreation becomes different; less frequent and more intense. Perhaps the result is less discussion about management;

(ii) the opportunity for a constructive peer influence on management practices is diminished. There is less repetition;

(iii) there is greater opportunity for managers living at a low need level to turn in on themselves and stop communicating with their peers.

4. *"A greater value is usually placed upon the higher need than upon the lower need by those who have been gratified in both."*

"Such people will sacrifice more for higher need satisfaction and will more readily be able to withstand lower deprivation." For example, they will find it easier to .... "withstand danger for the sake of principle." Maslow's comments here suggest that those who have been conservative managers and have adopted a long term managerial strategy will tend to adhere to these views even through difficult economic circumstances.

From the social scientist's viewpoint, therefore, it seems that any efforts expended on attempting to change graziers' attitudes toward conservative management are justified in that the effects of any success will be long-lasting. In summary, there is a psychological predisposition for poorer graziers to place greater pressure on their land because of the need for immediate financial gratification. Although this may simply be regarded as the statement of a truism, the psychological description afforded by the use of Maslow's hierarchy of needs is compatible with Child's (1974) description of management practices in arid zone farms in south-west Queensland.

Before the 1969-72 drought period, two types of pastoralists were recognised; those adopting an arid zone management policy which acknowledges the likelihood of prolonged drought and those clinging to temperate practices.

After the lessons of the drought Childs suggests that there are two different groups. (a) "There are those producers whose needs are for safety and survival. They are not confident of surviving the next climatic or economic crisis, they are in debt and lack the resources or skills necessary to overcome a crisis. Their motivation is to survive and this is often misdirected into trying to "beat" the seasons and the government." (b) "There are those whose needs are beyond the survival level. They know they can successfully overcome the next crisis. They have the resources, the skills, the experience and they have little or no debt. They can satisfy their personal ego or social needs."

Changing Overstocking Practices

The identification of the group of overgrazers who are motivated by their desire to gratify their lower needs is significant. This type of individual is probably the hardest to influence. His management strategies will remain rigid until his lower needs are gratified.

The Western Lands Act of N.S.W. (1901) (s.26(2)) states that land shall be allocated to applicants in the most need of additional land. The local Land Board is required by law to assess the needs of applicants for land. This analysis predicts that if an applicant is granted sufficient land to build his station up to something well in excess of one home maintenance area he would place less pressure on his land. This is consistent with section 18D(v) which states "a lessee shall not overstock...."

The local Land Board's current practice of identifying all the applicants motivated by their desire to gratify their lower needs and allocating a small parcel of land to each applicant will not prevent overgrazing unless all applicants receive sufficient land to give them land whose aggregate area is greater than one home maintenance area.

If the Western Lands Commission's desire is to ensure the long term productivity of the land resource it must continue to apply pressure to the local Land Boards to build up a few applicants to a reasonable area rather than to give many a small pittance.

The Land Acts, 1962-68, of Queensland gives the Commissioner the power to reject an applicant for a preferential pastoral holding if he considers that the applicant's financial means are inadequate (s. 57 (10)).

There is no doubt that there are economically secure individuals and companies who do adopt an exploitive attitude towards their stations. They do this for either personal reasons or because their perception of the environment in which they work is incorrect. It appears from the literature that gamblers and bad perceivers who receive a reasonable income are more receptive to extension officers' suggestions than those people who are forced to live at a level of low needs because of economic and motivational circumstances. Richards (1973) in a review of the psychological literature related to farming found that farmer income status is the key underlying variable to most psychological relationships. This suggests that adoption or non-adoption of recommended practices follows indirectly from a much more basic decision to compete or not to compete at a certain level in agriculture.

In the arid zone it is usually recommended that a pastoralist who places great pressure on his land should reduce the number of stock on one's property. The financially insecure grazier obviously has not the resources to take a short term reduction in income and is unlikely to adopt such a suggested practice. He is striving for survival rather than a model station; anything seemingly superfluous to his aim to survive will be rejected.

Conclusion

From the above information there seems to be little that administrators and psychologists can do to modify stocking strategies adopted by pastoralists motivated by their desire to satisfy their lower needs. The only course available to them is to elevate the grazier from his pressing financial difficulties through subsidies, grants or *sufficient* additional land. To provide pastoralists with sufficient land it will be necessary for many pastoralists to leave the industry.

Policies which keep marginal pastoralists and graziers poor will do so at the expense of the land resource. Marginal graziers must be given the opportunity to get big and if they like, to get out.

Gibbings and Reithmuller (1976) have found that economic criteria do not accurately predict a pastoralist's satisfaction with his way of life in the arid zone; so that it appears that as long as they can survive many marginal graziers will attempt to stay, perhaps to the long term detriment of their environment. In the final analysis then the decision of what to do about high debt pastoralists, who are motivated by a desire to gratify their low needs, is a political one, both in relation to the present situation and future planning. If it is decided that existing properties, given appropriate management practices, are potentially economically viable and that agricultural development is desirable in the arid zone then some influx of more land or financial assistance is required.

This assistance may take one of three forms; a grant of sufficient additional land, a direct financial subsidy to the individual grazier, or increased community or social services to the arid zone as a whole.

Our preference is for the first course of action. However, we must stress that to grant small pieces of additional land will not solve the problem. If it is only politically feasible to allocate small pieces of land there is a very strong case for leaving the allocation of land to the market place. In the market there are no arguments about justice equity, etc. Yates (1974) has eloquently described the huge familial and social costs which have to be absorbed within the pastoralist's property budget because of isolation. A reduction in this social cost, or in psychological terms, an easier gratification of belongingness needs, should both economically and motivationally provide an improved environment for the introduction of improved management systems for all pastoralists.

Finally, we must consider this paper in the light of future planning.

We should attempt to prevent the recurrence of the pastoralist whose behaviour becomes dominated by the economic vicious circle described here and by Childs, Gibbings and Reithmuller, and Yates. Economic pressure decrees short term decisions which especially in the arid zone eventually lead to further financial difficulties. Psychologically, the pastoralist by entering this situation is ever increasingly placing constraints on the limits of his own behaviour. Eventually, there is no behavioural choice, there are no real decisions for him to take and prospects of behavioural change in relation to management are nil.

The simplest method to avoid this situation is, of course, to ensure that potential pastoralists have sufficient financial resources to viably maintain a property on a moderate stocking level. Again this is a political decision but one which must be taken if we are to promote desirable land management behaviour among our arid zone managers.

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THE NEED FOR EDUCATION IN RANGELAND SCIENCE IN AUSTRALIA

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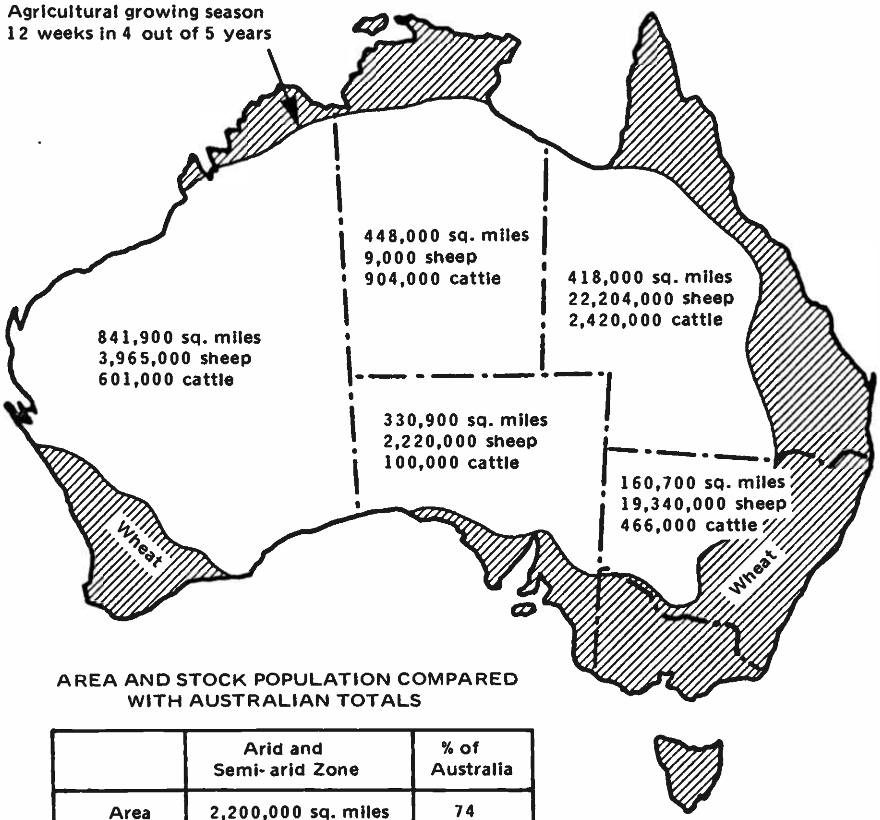
Abstract

Both the condition and the productive potential of Australia's rangelands indicate a neglect of these resources by governments, research organisations and teaching institutions. There is a need to synthesise existing specialised information into integrated managerial policies before a sound basis for training in and application of resource management in rangeland areas can be formed. Overseas developments in the sphere of range science as a discipline, and of range management as a profession can act as a guide to initiating a similar identity for the rangeland scientist in Australia. Australian tertiary institutions have not offered rangeland science as a major study area although many allied resource studies have been taught for many years. Several institutions have recently initiated moves to establish range ecology, rangeland management and range science as extensions of existing ecologically orientated science offerings. The need for range science to establish itself as a recognised tertiary discipline before its proponents can expect to be accepted as an identifiable professional group is emphasised.

Significance of Rangeland and Need for Management

The term "rangeland" applies to those ecosystems which are used primarily for the grazing of animals on natural pasture. While such ecosystems include considerable areas in the humid and subhumid regions of Australia, rangelands are generally considered to be those vast arid and semi-arid zones of the continent. A total of 2,200,000 square miles (.38 sq.m. = 1 sq.km.), or 74% of Australia, falls within these latter zones and supports one third of Australia's sheep and beef cattle. Figure 1 (Perry 1968) indicates the location and animal populations of the arid and semi-arid rangelands which produce export earning worth $450 million (Perry, 1967).



AREA AND STOCK POPULATION COMPARED WITH AUSTRALIAN TOTALS

	Arid and Semi-arid Zone	% of Australia
Area	2,200,000 sq. miles	74
Sheep	47,700,000	30
Beef Cattle	4,491,000	35

Fig. 1 Map of Australia showing arid and semi-arid zone and sheep and beef cattle populations (after Perry 1968).

The importance of Australia's rangelands should be gauged not only from pastoral production but also from the many other values and uses which natural grazing land provides as indicated by Lewis (1969) in Table 1.

TABLE 1

Some Potential Goods and Services
Supplied by Range Ecosystems

Grazing and/or habitat
Livestock
Wildlife
Water
Recreation
Minerals
Beauty
Preservation of a healthful environment
Preservation of natural or seminatural ecosystems for scientific study
Preservation of endangered species
Preservation of germ plasm for domestication or breeding
Timber (small value)

The Arid Zone Conference at Broken Hill reiterated the need for greater attention to be paid to the degeneration and lack of research in Australia's rangeland area. According to the Organising Committee, "It is abundantly evident that large areas of the more arid parts have suffered severe degradation of the vegetative cover. This degradation has resulted in lower productivity and low durability and represents a substantial loss to the nation" (Anon, 1970). Subsequently, Roberts (1972) and Leigh (1974) have made detailed analyses of the evidence of rangeland deterioration in Australia and recently Roberts (1977) has enunciated the sequential ecological processes involved in such deterioration.

The great need for natural resource managers in Australia's rangeland area has been stressed by Box (1969) who quotes the survey of Nelson and Schapper (1966) into managerial needs in rural Western Australia. This survey indicated that presently training was quantitatively insufficient and qualitatively inadequate. After 1976 an estimated 500-600 new farm managers would be required annually for the next 20 years, although the agricultural high schools and colleges of that State produced only 185 certificates and diploma holders each year. Considering all States, 1.7% of Australia is used for forestry, 3.7% for cropping and sown pasture, 57.1% is natural grazing and 37.4% is not used for primary production. Queensland with 82.4% has the highest proportion of natural grazing.

Many writers have noted the fact that virtually all those presently responsible for managing rangeland in Australia are self-taught or hold inappropriate qualifications for their job.

Principles, Factual Information and Research

Although many studies relating to individual facets of rangeland science have been undertaken over the years, the adequacy of current knowledge as a basis for the formulation of principles of management of particular regions or vegetation types remains questionable (Anon, 1970).

Since early years research workers have been aware of the potential of Australia's indigenous pastures (Richardson, 1924; Anon, 1927). However, the initial appreciation of the need for management of natural grazing lands (Griffiths, Davies & Sim, 1931) never developed into a research commitment to rangeland management so that today range ecologists ask "Where are the long-term grazing intensity studies in the arid or semi-arid zones of Australia? How many have been initiated? How many are planned to be initiated? (Van Dyne, 1970). It is true that although many scientists have undertaken good research on soils, plants and animals of the drier regions of Australia (vide Hilder, 1966; Williams, 1968; Squires & Hindley, 1970; Dudzinski, Pahl & Arnold, 1969; Wilson & Leigh, 1970; Marshall, 1970) grazing experiments and range management programmes have been limited to a few short term research projects (Woodroffe, 1941; Roe and Allen, 1945; Suijdendorp, 1955; Nunns, 1960). More recently the Joint U.S.-Australia Range Science Workshops have published a number of grazing management reviews based on Australian experience (Newman, 1971, Wilson, 1972, Burrows, 1974).

An examination of the published factual data on rangelands of Australia suggests that two basic constraints have been operative in limiting rangeland research in this country: (a) the lack of acceptable facilities and living conditions in inland areas generally (Box, 1969) and (b) the lack of graduate training in synthesis of specialist subject areas required in integrated rangeland research (Van Dyne, 1970).

Rangeland Science as a Discipline

Lewis (1969) points out that range management as a science appears to have had its origin in North America although it has been "enriched by the inclusion of concepts and practices developed or expanded in other lands". The comprehensive review of the early history of range management by Campbell, Price & Stewart (1944) indicates how serious studies of the grazing resources were not initiated until widespread deterioration of the western range caused concern in 1895. By 1938 Renner and his co-workers were able to list 8274 references in their bibliography on management of the western ranges. Despite a voluminous literature, range science, compared with other quantitative sciences has lagged behind. According to Lewis (1969) there are four reasons for this: (i) meagre research resources, (ii) Complexity of range ecosystems, (iii) inadequate methodology and (iv) low level of application of proven techniques and principles.

The philosophy and scope of range management as an area of study and practice have changed little with time. In 1914 Sampson maintained that optimum range management would mean "utilisation of the forage crop in a way to maintain the lands at their highest state of productiveness and at the same time afford the greatest possible return to the stock industry". In 1943 Stoddart and Smith defined range management as "the science and art of planning and directing range use so as to obtain maximum sustained livestock production consistent with conservation of the range resource. In 1966 Hedrick defined range management as "manipulation of the soil, plant and animal complex used by grazing animals" but a year later Pechanec (1967) distinguished between the narrower concern for forage and livestock as opposed to the broad professional concern for all the goods and services which rangelands can provide. With this background today's range management specialist has been defined, "not a generalist or social scientist and certainly not a superficialist, but rather a highly skilled applied ecologist thoroughly grounded in basic sciences and well-trained in the characteristics of range ecosystems, their potential uses, the impact of these uses on the ecosystem, the compatibility of these uses, and management for maximising values and minimising conflicts and costs; and schooled in the use of decision-making tools" (Lewis, 1969).

Apart from the North American developments in rangeland science, South Africa has been the only other country to undertake major training and research programmes in this field over a long period. Scott's (1947) "Veld Management in South Africa" and Roberts' (1968) "Pasture Science as a university discipline" reflect the way in which rangeland science in Southern Africa has developed primarily as an ecologically based field of study in resource conservation rather than in animal production. As in the American situation, the need for management action superceded the accumulation of a sufficiently sound factual research base for rangeland science in Southern Africa and as Roberts (1968) points out "Having established Pasture Science as a university discipline (in the 1940's) it was necessary that the subject acquire the objects, scope and depth that are required of university curricula.

Australian Training in Rangeland Resources

North America has 25 institutions offering range management at B.Sc. level, 23 at M.Sc. level and 14 at Ph.D. level (Lewis, 1969). South Africa has three universities offering pasture science (veld management) up to doctoral level. Australia has approached the task differently and offers a variety of agricultural and resource based training programmes but has yet to offer rangeland science as an identifiable discipline at undergraduate and postgraduate level.

In 1969 Box made a survey of training programmes for arid zone personnel offered in Australia by 53 organisations. The 45 organisations which replied, employed 434 scientists for the equivalent of 182 "scientific man years" in arid regions annually. These organisations indicated an overall increase of 150% in the number of scientists required in the next 15 years if arid zone research goals were to be achieved. The types of scientists required and the estimated relative demand for each is shown in Table 2 (Box, 1969):

TABLE 2

SCIENTISTS, BY DISCIPLINE, AND SCIENTIFIC-MAN-MONTHS EMPLOYED IN 1969 AND NEEDED IN 1985 BY 45 AUSTRALIAN RESEARCH AGENCIES

Discipline	Employed-1969		Needed in 1985	
	No.	SMM	No.	SMM
Agricultural scientists	45	230	79	672
Biological scientists	149	1015	272	2357
Earth scientists	135	266	136	796
Engineers	53	468	67	767
Natural resource scientists	32	151	77	557
Social scientists	15	54	24	196
	434	2184	655	5545

Relating these data to the number of universities in Australia at that time (1969 B.C.*) it was estimated that each university would be required to graduate approximately 200 trainees for arid zone work over the subsequent 15 years. The hazards of such quantitative predictions are obvious, but clearly Box's indications at that time were supported by the Arid Zone Conference Organising Committee when they noted the "lack of adequate research and management" adding, "Adequate courses are not available at either undergraduate or postgraduate levels at any university in Australia" (Anon, 1970).

Recently however, a number of universities and colleges have made meaningful efforts to develop and offer a range of courses, streams or major areas across the spectrum of land resources.

Although the Directory of Tertiary Courses (Anon. 1977) lists no courses in Rangeland Science, it includes a variety of allied courses as shown in Table 3.

*B.C. - Before Colleges

TABLE 3

RESOURCE COURSES AT AUSTRALIAN TERTIARY INSTITUTIONS (Anon, 1977)

Course	Number of Institutions	
	Universities	Colleges
Agricultural Science	8	8
Botany	14	0
Ecology	4	1
Environmental Studies	8	3
Rural Management	0	4
Wool and Pastoral Science	0	1

Included in the above courses are units in Agricultural Botany, Land Use, Conservation, Natural Resources, Grazing, Animal Husbandry, Pasture Production, Agrostology, Farm Planning and Property Management.

Individual majors, streams or subject areas at certain tertiary institutions appear to encompass facets of Rangeland Science as indicated in Table 4.

TABLE 4

OFFERINGS IN THE SPHERE OF RANGELAND SCIENCE AT AUSTRALIAN TERTIARY INSTITUTIONS (Anon, 1977)

Subject	Institution
Conservation	Dookie Agricultural College
Grazing Animal Husbandry	Hawkesbury Agricultural College
Resource Use and Conservation	Melbourne University
Agro-Ecology, Natural Resources	New England University
Pastoral Science, Land Resources	Queensland University
Ecosystem Management, Land Use	Griffith University
Resource Planning and Management	Canberra College of Advanced Educ.

In addition to the above offerings a number of institutions are presently preparing additional offerings in resource management for the 1978-80 triennium.

It is hoped that these will include innovations which will aid in developing a clear identity for the rangeland scientist in this country.

The logical development of such ecology based courses from the basic sciences through to integrated management programmes has much to recommend it, if training is to be well based and vocational in its objectives.

Heady has analysed the Range Curricula as offered at 15 institutions in the U.S. The general weighting of course components is given in Table 5 (Heady, 1961) and includes an indication of which subjects are required as compulsory core subjects by the Education Council for Range Management.

TABLE 5: Average weightings in 15 U.S. four year degree programmes in Range Management.

	Average semester Credit requirement	
Natural Sciences		35.98
Botany (Basic*, Physiology*, Taxonomy*, Ecology*)	14.82	
Chemistry (Inorganic*, organic*)	10.53	
Geology	2.13	
Physics	2.20	
Zoology (Basic, Animal Ecology)	4.26	
Others (Genetics, Entomology, Bacteriology)	2.18	
Mathematics and Engineering		9.38
Mathematics (Algebra*, Trigonometry*)	4.98	
Statistics	1.11	
Engineering (Drafting, Surveying)	3.29	
English and Social Sciences		22.11
English (Composition*, Speech, Writing, others)	10.10	
Economics (Basic*, Agricultural)	6.39	
Social Sciences, History & Government	5.62	
Agriculture		21.22
Orientation	1.16	
Agronomy (Elements, Forage crops)	3.84	
Animal Husbandry (Basic and Production*, Nutrition and Feeds*)	9.84	
Soil science (Basic*, others)	5.44	
Others	0.94	
Other Wildland Uses		8.60
Forestry	4.49	
Watershed Management, Soil Conservation	1.78	
Wildlife Management	2.33	
Range Management		18.29
*Agrostology, Range Plants. Range Ecology	6.80	
*Methods, Utilization, Condition and Trend	3.24	
*Management, Improvements, Planning, Economics, Policy	5.85	
Seminar	0.96	
Field Trip	1.44	
	Total	115.58

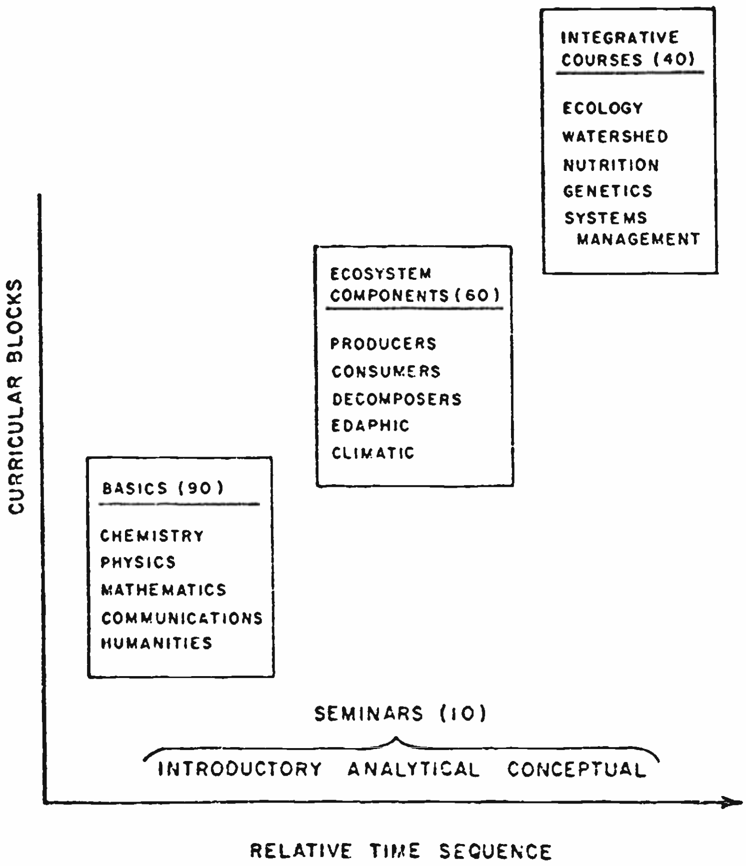
* Subjects required in all curricula

Vickery (1976) in referring to the present fragmented departmental approach to land resource problem-solving, has labelled the situation in the States "chaotic". The most recent Kalgoorlie Arid Zone Conference (Anon, 1976) has put before the Standing Committee on the Arid Zone a motion calling for the establishment of tertiary courses specifically for the training of personnel working in rangelands. The Newsletter of the Australian Rangeland Society has distributed a call for professional training of rangeland scientists in Australia.

If the Rangeland Scientist is to be recognised and accepted within the Australian scientific, pastoral and administrative communities, he will require the level of identity and professionalism that Ecologists had first to acquire before they were recognised as a meaningful group with problem-solving expertise. To gain such identity, training appropriate to any self-respecting professional will have to be developed, offered and applied.

Curriculum Contents

Australian tertiary institutions will need to clarify objectives for Range Science courses before the details of curricula can be meaningfully proposed. The American experience in rangeland and natural resource training has a number of guidelines worthy of consideration by Australian institutions. Van Dyne (1969) has suggested a sequential four year programme for natural resource training as shown below.



It is not inferred that the emphases and balance of the American curricula are necessarily appropriate to the Australian situation, and the contribution of soil science and meteorology (including drought strategies) may warrant particular attention in the Australian context. It may well be that there is a strong case for curricula in different States to be tailored to meet the particular soil-climate-vegetation-management situations in each State.

It is hoped that the Australian Rangeland Society will use its influence and collective knowledge to initiate the developments referred to in this paper.

A REVIEW OF THE OBJECTIVES OF THE AUSTRALIAN RANGELAND SOCIETY

J.G. Morrissey & Gwynne Hughes

It would be fair to say that this society was created because a group of rangeland scientists arrived at the conclusion that there was a need for change in which Australian rangelands are used and managed. It was created as a forum where an exchange of ideas could result in improved rangeland management in Australia. It was recognised that there was need for communication between the administrators, managers and scientists to ensure that the necessary changes did occur. This concerned group set up a hierachy of objectives for the society, gave the society a name and here we are today, largely it is predicted, a group of scientists setting about a discussion in scientific terms on matters of science in rangelands.

What ar ethe objectives of the society, how are we progressing toward these goals and are there any changes needed to redirect the society towards the goals.

The second article in the memorandum of the Australian Rangeland Society consists of the hierachy of objectives for the society and the first and second items in this hierachy are:

(a) To promote the science and art of using Australia's rangeland resources for all purposes commensurate with their continued productivity and stability.

(b) To encourage and develop an awareness of the need to conserve the inherent resources of the Australian rangeland areas.

The remaining objectives are largely devoted to formalizing the means by which (a) and (b) above will be realized.

Despite a resurgence in mining and a dramatic growth in the tourist industry, the majority of the operational management discussions in our rangelands are still and will continue to be made by the managers of sheep and/or cattle grazing enterprises. These people have experience in overcoming the day to day problems of property management, and the direction and nature of the changes that occur in rangeland management technology must take into account this experience.

The achievement of the objectives of this society depends on the nature of the discussions made by these managers and the society must therefore attract managers to it, so that they can gain the insight into rangeland management that is available from rangeland scientists. Similarly, the efforts of the scientists must be tempered by the experience of the managers.

At present, the society does not attract sufficient managers. 21 per cent. of its membership is made up of managers, 2 per cent. are administrators. The majority, 77 per cent. are people with scientific training professionally engaged in rangeland investigation. As might be expected, the society caters largely for the needs of the majority. It provides a human group environment in which scientists can feel at ease and find social rewards. This group environment created by the society is less able to provide opportunity for satisfaction of the social needs of the rangeland managers who have attitudes and beliefs much different to those of rangeland scientists.

The formation of human groups and the development of group environments that are rewarding to their members is normal human behaviour and the pattern of development of this society may well be for it to accumulate more and more people with ideas and fewer and fewer people with the ability or opportunity to make the type of descisions that will result in the ultimate achievement of the society's objectives. The society must recognise this danger and strive to provide a group environment attractive to more managers.

The society's journal is a significant component of the group environment of this society. The style is clearly that of a scientific journal and it provides scientists with the opportunity to be identified with other scientists. It is unlikely the people involved in Australian rangelands who are without scientific training would feel compelled to read or contribute to it. The argument is not that the publication is a poor journal, rather that given the objectives of this society, that the journal is incompatible with the achievement of those objectives. The journal caters largely for one section of the society's membership and though it caters for the majority of members, it should be designed to attract more of the people who ultimately are the decision makers in Australian rangelands.

Obviously it can equally be argued that if the society provided a less satisfactory environment for rangeland scientists, that it would be weakened by the loss of members with scientific training. However, people who are employed as investigators in Australian rangelands have a responsibility to ensure that the work they do is relevant to the problems faced by managers and that the results of their work does become part of the operational decisions making process. Researchers are in a special position, and they have greater opportunity to recognise the requirements for an effective communication process between themselves and rangeland managers. They should be prepared to accommodate the demands of this communication process. Both managers and investigators within the society have recognised that there is a communication gap between them, but the onus to bridge this gap rests more with the investigators. If the communication process can be enhanced by changing the style of the journal, this should be accepted as part of the requirement for meeting the objectives of the society.

The objectives of the Australian Rangeland Society are reasonable, however the achievement of these objectives depends on attracting managers to the society. An avenue that may yield clues on how to make the society relevant to rangeland managers would be to explore why a large proportion of the manager members are South Australians, i.i. 16 out of 31.

CONDITION ASSESSMENT IN PRACTICE

G. Bastin and G. Pearce
Animal Industry and Agriculture Branch
Alice Springs.

In 1976, the Animal Industry and Agriculture Branch of the Department of the Northern Territory commenced a systematic survey of pasture conditions on cattle stations in the Alice Springs district. To date, seven stations covering approximately 14,300 sq. km. have been assessed.

The ultimate use of the survey is to assess a grazing capacity for the watered area on each station from current pasture condition. This assessment has application at all levels in the grazing industry including:-

1. Use by station management -
   (a) to match stock numbers and classes to feed supplies available throughout the year.
   (b) to plan and operate property budgets.
   (c) to assess property development and maintenance programmes.

2. Use by lending institutions as a criterion for granting loans.

3. Use by Lands Branch administration to establish pastoral leases of a viable size and to set equitable land rentals.

4. Use by the Animal Industry and Agriculture Branch
   (a) for the prevention of pasture deterioration or soil erosion
   (b) to assess the effects of drought, fire or flood and assist in the preparation of policies to prevent or ameliorate the effects of natural disasters and provide assistance.
   (c) for advice to station managers on the improvement of the productive potential of their pastoral leases.
   (d) to compare the potential of investment in pastoral lands with other alternatives.

Method of Condition Assessment

A definable procedure is followed for the planning and conduct of each station survey.

1. Mapping

The different land types are interpreted on 1 : 80,000 scale aerial photographs using the "Land System" classifications of Perry etal (1962).* These photograph patterns are then mapped onto the 1 : 250,000 scale station map. The station map allows greater mapping accuracy than is available with the 1 : 1,000,000 scale Perry etal (1962) map. Where prior knowledge of a particular area does not agree with the Perry etal (1962) description, a different interpretation has been placed on that photograph pattern. The land system boundaries and classifications on the station map are checked in the field at the time of survey and where necessary, corrections made.

2. Site Selection

A minimum of one condition assessment is made of the most susceptible land system that is accessible at each watering point. The decision on susceptibility is based on the following criteria:-

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(a) the pasture's palatability to cattle and hence the grazing pressure that it will experience.
(b) the importance of that area to animal production
(c) the significance of that land system's area in relation to the total area watered from the bore.
(d) the sensitivity of that area to disturbance e.g. risk of erosion following over-utilization of the pasture.

Time available in the field is a limiting factor and it is not considered worthwhile to sample from watering points that are surrounded entirely by spinifex sandplain or mulga shrubland with a perennial understorey. Both of these communities have low grazing capacities and are relatively stable to grazing. Sampling sites are selected at approximately 3 km from the watering point as a compromise between the sacrifice area, and the region of low utilization at a considerable distance from water. Studies by Low Et al (1973) have shown that in a well watered paddock where the maximum distance that cattle could forage from permanent water was 10.4 km, cattle rarely grazed beyond 8 km even when vegetation was sparse and dry. For less well watered stations, it was observed that cattle grazing out as far as 9.5 km only did so when pasture condition was poor and that these cattle were losing weight. To avoid estimates of grazing capacity that would result in over-utilization of pasture at an intermediate distance from water and weight loss in cattle through the distance involved in foraging, the watered area in this survey has been set at a radius of 8 km from the watering point. On this basis, four of the seven stations so far assessed are fully watered.

In the field, a check is made that the survey point selected on the aerial photograph is typical of the ecounit within the land system which is to be assessed. If the site is atypical, then an attempt is made to locate a more representative sampling area at some other point in the surrounding area. If still unsuccessful then a site is chosen in the next major land system that is accessible.

3. Condition Assessment

When satisfied that the sampling site is suitable, a numbered picket is driven in, a colour photograph taken and the site location permanently marked on theaerial photograph. The condition assessment is made over a five to ten hectare area round the site peg using the 'Standards for Testing and Assessing Range Condition' (STARC) developed by CSIRO and the Animal Industry and Agriculture Branch. (Lendon and Lamacraft, 1976). This involves listing all the grass and forb species present and assessing the percentage contribution of each species to the total dry weight of the pasture. The major species are estimated individually to the nearest 5% with the minor species being grouped as 'Other Grasses' or 'Other Forbs' and assessed similarly. Finally, a condition score is arrived at by comparing the pasture composition of the site against that of the reference for the same ecounit. For example, two different ecounits occur in the Bushy Park (Perry et al, 1962) land system; Mulga (Acacia aneura) with annual grass understorey and Mulga with perennial grass understorey. Areas of each ecounit in excellant condition have been located and the pasture composition of the appropriate area is used as the benchmark against which to score the same ecounit when encountered on survey.

It has been necessary to construct pristine pasture compositions in the absence of suitable exclosed relicts. As an example, areas of the Calcareous Shrubby Grassland ecounit that have rarely been grazed by cattle have been so drastically altered by rabbits that it is impossible to locate areas in undisturbed condition.

4. Recording of Data

A coding sheet has been developed by the CSIRO division of Land Resources Management in Alice Springs for the recording of site location, soil characteristics

.../3

pasture composition, trend indicators and station management details. This information is then in an available form for punching onto cards and sorting by computor.
Several advantages of the STARC method have thus far become apparent. This progress has been tempered to some extend by problems still requiring attention.

Advantages of Condition Assessment Method.

1. A permanent record of assessment sites is obtained.

2. A numerical and photographic record of condition at each site allows an objective measurement of trend on a resurvey and a direct comparison with other sites in the same ecounit.

3. The method is used directly. Once pasture composition has been determined, it can be compared against the relict and a numerical condition score obtained whilst in the field.

4. The method is easy to use. Training involves the repeated estimation of species composition inside quadrats and the cutting and weighing of these species. This continues until a sufficient degree of accuracy is obtained between actual pasture composition and the assessment given by each operator. Since individual and bulked species are estimated to the nearest 5%, then each assessor's estimates should ideally come within a 5% range of the actual pasture composition on each assessment.

When individual operators are confident in their assessments, further cutting and weighing is only necessary as a periodic check and following a pasture growth season where there have been significant species compositional changes.

5. A satisfactory level of between-operator repeatability is achieved in the individual assessments made at each site. In homogenous plant communities (e.g. Mitchell grass or Mulga/Perennial grass) individual assessments of pasture condition are very similar and condition scores obtained by each operator rarely differ by more than five percentage points.

The variability amongst operators increases in the more diverse communities where up to ten equally important species can occur (e.g. the Cottonbush (*Maireana aphylla*) flat ecounit of the Hamilton (Perry et al 1962) land system). Where such communities are likely to be encountered on survey, an attempt is made to have at least two pasture ecologists present. The consensus pasture composition is then a good estimate of the actual pasture composition.

6. The assessment method is a rapid and systematic technique for assessing the condition of the important land systems on a station. Six to seven sites can be covered in a day and a station of 2,500 sq km in five days.

Problems Requiring Attention

1. It is not always possible to use the pasture composition of the reference area as the benchmark against which to score survey sites without some allowance first being made for rainfall variability.

Most of the present reference areas are located close to Alice Springs (275 mm average rainfall) and although a site selected in the more arid regions is recognizably similar to the ecounit in which the defined relict occurs, the lower rainfall may mean changes in species composition. For example, productive perennial grasses (*Enteropogon acicularis*, *Digitaria*

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coenicola) that form a significant part of the Open Woodland ecounit reference are often lacking in the survey area. The problem arises in deciding whether climate, soil factors etc. prevent the successful existence of these species or whether they have disappeared through overgrazing. If the latter is the case, then the site can be scored against the reference pasture composition and down-rated in condition accordingly. However, if environmental conditions apart from grazing by cattle prevent the existence of these species, then the benchmark must be modified so as not to penalize these areas in condition.

2. Differences in seasonal rainfall over the extensive Alice Springs district (370,000 sq km in area) can be a problem in comparing survey sites against the reference areas. Unless general rains have fallen over the whole area, different seasonal rains can produce significantly different pasture compositions between the survey and reference areas. Unless allowances for different seasonal conditions are made in the proportion of each species allowed in the reference and site, a biased condition score for the site may be obtained.

3. A problem can arise in the assessment of preferred pastures if no allowance is made for the utilization of the more palatable species. Failure to make this allowance may mean that a low proportion of total weight contributed by the preferred species, due to transitory heavy grazing, results in an incorrent condition score for the site. A shower of rain could quickly restore this loss through the regrowth of perennials and the germination of annuals. It is different to decide what level of utilization should be allowed before penalizing the site in condition.

4. The widespread fires experienced in 1976 have presented a problem in station assessments. Unless the reference area has also been burnt, it is not yet known what recovery period is necessary for a fair and meaningful assessment of burnt areas. 'Fireweeds' (e.g. Solanum spp) make up a considerable proportion of the regrowth following a fire, and these species lower condition when assessed against the unburnt relict. A period of perhaps two complete growth seasons may be required to allow re-establishment.

5. It is not yet known what sampling density around each watering point is required to obtain a comprehensive picture of each land system's condition class. At present, sampling from each water usually means that the major land systems are sampled five to eight times on each station although this is dependant on station area and the density of watering points.

This problem is currently being investigated as a research project by the CSIRO Division of Land Resources Management in Alice Springs.

6. No definitive relationship has yet been derived between the current condition class of an ecounit and the number and productivity of stock that can be safely grazed on it.

Tentative recommendations have been made from estimates of seasonal forage production on different pasture types and knowledge of animal preferences , requirements and likely levels of utilization. This is a forage supply method for determining the grazing capacity of areas in excellent condition which is then modified by the current condition score to give a lower grazing capacity.

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Conclusion

The STARC method of condition assessment provides a simple and rapid technique for determining the condition of grazing areas on pastoral leases in Central Australia. However, several problems still remain for the proper implementation of the method and the interpretation of the condition scores obtained.

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RANGE CONDITION ASSESSMENT: HOW MUCH DO WE KNOW?

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The concepts of range condition assessment have been widely (though not universally) accepted in principle by personnel concerned with rangelands in western New South Wales. The methodology and its application in the field has yet to be determined, although work is currently in progress on these aspects.

The ecological approach (Dyksterhuis 1949) has much to commend it and will undoubtedly be used as a yardstick against which other methods may be measured, although some modifications to the original method may be required for local conditions. Unfortunately, the ecological background required for the successful application of this concept in western New South Wales is far from complete. That grazing by domestic animals and rabbits (not necessarily in that order) has wrought great changes in the vegetation of the rangelands of Australia is unquestioned. What is open to question is how much of the present-day condition of the vegetation is due to grazing and how much is due to other constraints such as edaphic factors, climate, and natural phenomena such as floods and fires.

The authors of this paper form part of the New South Wales Range Assessment Committee and as such have the responsibility of selecting study areas within different range sites for the testing of assessment techniques. Selection is based on the criterion that the areas within each range site have the same topographic and edaphic characteristics but support a different assemblage of pasture plants, and the difference in composition is assumed to be a reflection of past grazing intensity. The three range sites examined to date include bladder saltbush vegetation on the Riverine Plain, bladder saltbush on desert loam footslopes, and mulga on sandy rises. The main difficulty, so far as the authors are concerned, has been to isolate obvious effects of grazing by domestic stock from natural and uncontrolled constraints which periodically impose themselves upon the country.

The order of the four constraints, in terms of impact on the composition of rangeland vegetation, could be

(1) Edaphic factors
(2) Climate
(3) Natural phenomena
(4) Stock management

The four, all of which may be inter-related, will be considered in that order.

(1) Edaphic factors

These are accounted for in site selection by definition. They are of no great concern other than that small differences in soil characteristics, e.g. depth of sandy topsoil, gilgai formation etc. can produce marked vegetation differences. Few paddocks have a uniform soil type, fewer have uniform edaphic features.

(2) Climate

This is probably the most variable and difficult constraint to understand. Long-term climatic factors such as seasonality and amount of rainfall, temperature and wind conditions have an over-riding effect on the type of plants likely to occur on any soil type. However, specific seasonal events can result in marked, shorter-term changes. The accepted folk-lore that summer rains produce grass and winter rains produce forbs is often severely modified. There would appear to be a "law of occupancy" where once a plant has become established on an area it inhibits other plants that may have germinated at the same time, or during a subsequent sequence of climatic events. A dense cover of a vigorous annual such as *Erodium crinitum*, brought about by favourable autumn and spring conditions, could modify the micro-environment to the extent of preventing or reducing the establishment of less vigorous species. While this applies mainly to annuals it can markedly affect the perennial vegetation, particularly during the phase of establishment of new populations. A run of years with favourable summer rainfall followed by a sequence of good winter rainfall years can change the general composition of a pasture quite dramatically and variable seasonal conditions may keep a pasture in a continued state of flux. For the vegetation of western Queensland where a similar situation is apparent, Blake (1938) used the term "fluctuating climax". Allen and Roe (1943) and Everist (in Roberts 1972) described the climax as "opportunistic" as it is the result of rainfall distribution at any particular time, and to a lesser extent to the effect of the grazing animal.

(3) Natural phenomena

These factors which relate to rapid destruction of the pasture, may occur by fire, flood or by pests (rabbits, locusts etc.). Examples of great changes brought about in this manner have been observed on saltbush country. Extensive areas of saltbush killed by local flooding have been revegetated by poverty bushes (*Bassia* spp.). On areas from which the saltbush had been removed by fire, grass swards have now established, although in adjacent unburnt saltbush stands grass is a minor component. Re-establishment of saltbush in affected areas will be a slow process.

(4) Stock management

The effects of this constraint were not always easily discernible in the field, nor were they easy to isolate from the effects of the other variables. Excellent fence-line differences were found but these were mostly related to holding paddocks and homesteads where the areas have been largely denuded of plants and kept that way for fire breaks. This continuous removal of vegetation by grazing and trampling rarely allows any successional community to develop, apart from a cover of annuals in the cooler months. These degraded situations represent the lower condition classes.

The top condition classes, by virtue of definition for the project in hand, have been relatively easy to locate. These are the "best" areas available in the same locality as the lower classes. Contrary to the opinions of some, remnants of pristine vegetation are exceedingly difficult to find, even to the most diligent searcher (always assuming that the searcher knows what to look for!).

Areas in intermediate condition class have been difficult to find even around bores, where the "piosphere" should exhibit an extended intermediate zone between the sacrifice area and the lightly grazed distant zone. Around old bores no longer in use, the "degraded" area extended for little more than 100 m. Around most bores currently in use the vegetation showed little gradual change with increasing distance from the bore. This lack of intermediate composition both in the "piosphere" and in paddocks in general would suggest that the vegetation is very resilient and that moderately degraded areas have recovered with the run of above-average rainfall years.

Occasionally found were fence-line differences showing changes in species but in which both pastures had the same plant type (e.g. in some areas the perennial grass *Eragrostis eriopoda* has been replaced by another perennial *Aristida browniana*. Both species appear to be moderately palatable to stock and the change in species seems to reflect the influence of climatic variables on establishment and suggests that time of utilization could be equally important as degree of utilization of the pasture.).

Conclusion

Grazing by domestic stock can undoubtedly affect the composition of the vegetation. However, before we can expect to monitor range condition successfully and manipulate condition status by stock management more information must be obtained on the effects of the grazing animal relative to, and together with, uncontrolled constraints which act upon the rangeland ecosystem. Perry (1967) states "An understanding of the growth, development, production, and reproduction of the important plant species and the principles governing their response to various factors is basic to community productivity and conservation, to the precise definition of range condition and trend standards and to the interpretation of data from grazing experiments. In Australia very little precise knowledge is available for even such important plants as mulga, Mitchell grass, saltbush, and bluebush." During the past ten years further knowledge has been forthcoming on some of these species but overall the situation has shown little change. There is still much to be learned about the above plants and other key or indicator species such as *Eragrostis eriopoda, E. setifolia, Maireana pyramidata, M. sedifolia, M. astrotricha, Bassia diacantha* (and other *Bassia* spp.), *Cassia* spp., *Thyridolepis mitchelliana, Enneapogon avenaceus* etc.

We feel there is a need for further study of the establishment, growth, reaction to grazing and regenerative ability of the major species, together with studies aimed at defining successional patterns in vegetation communities under different grazing and climatic conditions. Such studies, carried out concurrently with research on range condition assessment would provide a basis on which to establish condition and trend methodology and reduce trial and error management exercises.

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RANGE ASSESSMENT: HOW MUCH SHOULD A MANAGER DO?

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The argument that rangeland managers should assess the condition of their vegetation stresses the serious costs, to the nation and to the manager, which may arise from failing to do this. At this level the argument is crude and it is no wonder that few managers do assess their range. There is a need for someone to spell out the benefits and costs of range assessment. The following sets out a framework for such an attempt.

Perceiving the need to assess range

Initially it is necessary for the manager to perceive that a problem exists. He will do this when he perceives that the situation he observes may be different from what he considers it should be. Beliefs play a very important role in determining that which is perceived.

Deciding when to assess

A manager should assess his range when the costs of assessing it appear to be less than the expected benefits that will accrue from the assessment.

It must be remembered that there is already a crude form of assessment which is based on habit, custom and tradition. These should be abandoned whenever the cost of the resultant errors and the value of the experience gained from a new process of assessment are greater than the cost of learning and the cost of using this method to assess his range.

Deciding how much assessment to do

This is perhaps the hardest thing for a manager to determine. He must realize that

- as more observations are made the accuracy of his estimate of range condition increases at a decreasing rate;
- the per unit cost of accuracy (in time and effort) increases as the number of observations made increases.

By realizing these two points the cost of achieving various levels of accuracy and hence levels of confidence in one's estimates can be made.

The value of range assessment depends on the magnitude of the degradation which is possible without and with assessment. Much of this depends on the ability of a manager to be flexible and to alter his managerial decisions as trends become apparent. Range assessment provides an early warning system.

Even using range assessment it is possible to make a mistake. The seriousness of such a mistake will depend on the probability of making it and the size of the mistake. When a manager decides on the accuracy of assessment he will adopt he must realize that he is assessing his range to reduce the probability (likelihood) of making a mistake and/or the size (cost) of making that mistake.

The value of an assessment does not only accrue to the immediate situation as with assessment there is learning and improved biological perception. Learning is a cumulating process, hence allowance must be made for the value of the "experience gained" from assessment as well as the immediate value of the information.

Assessment takes time and hence may delay decision-making. Particularly, high levels of accuracy take time to achieve. Such delays may mean that assets are not fully employed, however, such an approach may produce a more certain income.

Finally the value of accuracy and the seriousness of losses resulting from mistakes are personal and depend on a long list of items including the psychological nature of the manager, his wants, tastes, preferences, his family obligations etc.

In summary, a manager should spend no more time and money on range assessment than this additional information is worth to him. There is no reason why he should spend his money to assess the range for future generations.

Acknowledgement

This short essay is drawn heavily from the principles contained in the Introduction to "A Study of Managerial Processes of Midwestern Farmers" by G. L. Johnson, A. N. Halter, H. R. Jensen and D. W. Thomas. Publ. Iowa State Univ. Press 1961, xi + 221 p. The Introduction was written by Johnson and Halter.

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Range condition surveys with an interval of 2 years.

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It has been said in the last few years that the management of rangelands must proceed through three stages:-

(1) An inventory of the natural resources;

(2) Determination of the successional stage of the vegetation resource (the range condition);

(3) An assessment of the change in the condition of the natural resources attributable to management (the range trend).

If one accepts the view that the only major manipulation open to rangeland managers wishing to improve their land lies in the adjustment of stock numbers, then in theory, stocking intensity must be altered flexibly according to the way range trend is going. Range assessment has reached the third of the above stages in central Australia, and this paper considers the derivation of range trend from the difference in results of two condition assessments with a time lapse of two years.

In Oct.-Nov., 1974 the Department of N.T. Animal Industry and Agriculture Branch and CSIRO jointly carried out a survey of four cattle stations (7700 sq. km.) of the Burt Plain, north of the Macdonnell Ranges, C.A. In late 1976, these organisations re-surveyed the same area. The aim of the first survey (Burt Plain Survey) was to describe and map the area into ecological land units based on cattle usage. At the same time, the STARC methodology of assessing range condition was tested. The second survey conducted by the A.I. & A. Branch, the Grazing Capacity Assessment, used the STARC condition method as a basis for setting safe stocking levels on some important rangeland types of the district. Data was collected from approximately 60 sites on both surveys.

The Study Area

There are five major rangeland types on the 7700 sq. km. of central Australia under consideration. The depositional surfaces of Hamilton land system adjacent to the northern foothills of the ranges, (Perry, 1962) contain a floodout unit, treeless with annual grasses and forbs growing on eroded, texture-contrast soils ("Cottonbush Floodout" unit). Within the same land system, open woodland occurs on coarse-textured alluvial soils, having scattered palatable shrubs and trees over nutritious short grasses and forbs (e.g. Enneapogon spp., Aristida contorta). This "Open woodland" grades into mulga with an predominantly annual understorey on more loamy soils. This "Mulga-annual" unit grades in turn into more typical mulga rangeland with perennial shrubs (e.g. Eremophila spp.) and grasses (e.g. Eragrostis eriopoda, Monachather paradoxa) extending out into the fringes of the spinifex sandplain. Interspersed along the foothills are areas of Mitchell grassland (Astrebla pectinata) characterised by gently sloping, treeless plains of heavy clay soils.

For the years 1974-1976 during which the two condition assessments were carried out, rainfall far exceeded the long-term district average of 275 mm. per annum, with 859 mm. for 1974 and in excess of 400 mm. for both 1975 and 1976. Observations in the field on both occasions confirmed that the vegetation conditions reflected near-optimum growth conditions for central Australian plant communities.

The comparability of the surveys.

Range condition scores were obtained on both surveys using the same assessment method (STARC). Additional data were collected in 1974 on soils and woody plants during the development of a reliable range condition methodology. From this came the STARC concentration on the botanical composition index (Lendon and Lamacraft, 1976), and this has become the common ground for comparison between the two surveys.

The details of the second survey procedure in 1976 are spelt out in another paper to this meeting by G. Bastin and G. Pearce. In summary, sampling sites were chosen at fixed (3 km.) distances from cattle watering points. By contrast, the first survey selected sites without regard to the proximity of water, the aim being to obtain ground truth for mapping photo patterns. The result is that, when matching the location of sites for comparison, we can consider two approaches:

(1) The total number of sites assessed in each survey can be averaged (a) for all sites and (b) for each of the five rangeland types ("open woodland", "mulga-annual" etc.)

(2) Pairs of sites, one from each survey, can be identified in the same piece of rangeland, not further than 2 km. from each other.

Results of total sites combined and sites per rangeland type (1) are shown in Table 1. Condition scores between the two surveys do not differ significantly based on Students "t" Test (assuming normal distribution of data) and the Wilcoxon Matched-Pairs Signed-Ranks Test (no assumption of normality). An examination of the coefficients of variation of scores from both surveys shows reasonable agreement, suggesting that this consistent pattern of variation comes from two samples of the same population of plant communities. Thus, when the assessors were faced with the data from two surveys and asked "How representative of the rangeland types are the two sets?", Table 1 shows that the two surveys can be compared.

Condition scores and distance from water

Another source of potential variation between the two surveys might have been the location of sites sampled in relation to the distance from the nearest watering point. The 1974 survey positioned sites for mapping purposes, in a range of 0.5 km. to 9.2 km. from waters, whereas the 1976 survey selected sites that were in a certain land system, mostly around 3 km. (range 2 km.- 6.5 km.) from a watering point, and easily accessible from station roads. When the hypothesis that distance from water has an influence on range condition, as assessed in these two surveys, was applied to the data, a significant relationship was found only for the Open Woodland in the 1976 survey (Table 2). The data shown includes all sites; the same analyses were carried out excluding sites that were closer to water than 1.5 km. and further from water than 6 km. Results remained not significant. In practice, these results would suggest that, for relatively well-watered and well-fenced areas, re-assessment sites located independently of watering points (excluding the immediate sacrifice area) would adequately describe the condition of the general area of the particular rangeland type. More systematic research is being undertaken to determine a station-wide strategy for range condition description.

Repeat sites from same locality

Of the 117 sites assessed for both surveys, 23 pairs were located in close proximity and could be considered as "repeat sites". The condition scores for each pair were compared using both the Wilcoxon and "t" tests with the result that no significant difference could be detected either between all 23 pairs or between groups of pairs from particular rangeland types. An examination of the scores of each pair shows that 52% fall within 0-10 STARC points of each other and 82% within 0-20 points.

Condition class and rangeland type

Figure 1 shows the condition scores distributed into condition classes of 20% intervals. More generalised figures are given in Table 1, in the forms of (i) an overall mean score and (ii) the percentage of sites scoring above 60%, for each rangeland type. These class intervals are commonly used to classify the degree of improvement or degeneration of country, and the above 60% condition rating has been taken as the management goal for the most productive and stable state for livestock production.

Considering first the two mulga rangelands, the mulga-perennial unit is predominantly in good condition in both surveys. The mulga-annual unit is in good condition in 1976 and "high-fair" condition in 1974. Open-woodland rates in fair condition and cottonbush floodout in predominantly poor, for both surveys. It is interesting to note that the condition of these four rangelands coincides inversely with the way Low (1972) observed present-day cattle grazing preferences within one 153 sq. km. paddock of the area.

Mitchell grass plain is also an attractive grazing unit for cattle, and the results suggesting that this is the only rangeland type in worse condition in 1976 than in 1974 (while not a significant difference at the 5% level) may warrant further explanation. It was noted that many Mitchell grass sites in the second survey were limited in area and surrounded by other less-preferred rangelands: these sites were thought to be target grazing areas under heavier and more constant use than the sites sampled in 1974 on more typical, extensive Mitchell grass plains.

Range Trend

We began with the proposition that range trend, the change in the resource base brought about by management factors, may be deducable from the difference between two assessments of range condition with a time interval. The data presented from two condition surveys with an interval of two years does not show a significant difference (at the 5% level) that can be claimed to be a real change, i.e. range trend. But that is not to say that no trend has occurred, and the following points should be made.

(1) The method of obtaining the two sets of condition scores may not have been sensitive or precise enough to detect a small, but real, trend change of say, 5-10%, given the short time interval between assessments.

(2) Two years is a much shorter time interval in which to expect a detectable trend in rangelands than the more usual 5-10 year interval used in range management elsewhere in the world. But all three years, 1974-1976, were exceptionally wet; many plants that were normally annuals perennated and reproduced right throughout this period, and plant communities became appreciably denser. It is to be expected that at such a time - a favourable "pulse" in arid lands - the plants would respond in an opportunistic way. However, it should be stressed that we were not sampling simply seasonal effects : the STARC assessment takes account of erratic, seasonal fluctuations by setting standards from the composition of undisturbed reference areas at the beginning of each assessment survey.

(3) Under this assessment method, range trend would be inferred from a real change in the composition of the pasture, and we need to consider what effect management factors would be having on composition shifts. We know that cattle numbers rose to 1½ - 2 times the stocking levels that applied during the previous few, "dry-normal" years (records from 3 of the 4 stations). Grazing management was not altered appreciably during the study period, but the effect of the expanding cattle population would have been masked to a great extent by their widespread use of the area owing to the abundance of preferred surface water for drinking (Hodder, pers. comm.).

In summary, if the general shift towards higher condition classes as shown in Fig. 1 is real, then improvement has occurred during two wet years in spite of, not because of, management of these lands. We would add a further qualification to the non-significant differences reported in Table 1. By averaging STARC scores across condition classes, we may well have masked regenerative processes occurring at different rates throughout the range condition spectrum. When we related the subjective trend (up, down or static) that assessors were asked to give at each site against condition scores grouped as (i) above 60%, (ii) 40-59%, and (iii) below 40%, we found a pattern. For both surveys, the majority of sites in above 60% condition were assessed to be in upward trend. At the other end of the scale, more sites below 40% were assessed in downward trend than in static or up. It was in the middle range, 40-59% sites, that most sites were assessed as either stable (1974 survey) or downward (1976 survey). The practical consequence of this may be that most effort in sampling range trend should be expended on sites in the median or "fair" condition class.

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TABLE 1

Mean STARC scores, standard deviations, coefficients of variation, number of samples, and tests of significence for the different rangelands in the 1974 Burt Plain and 1976 Grazing Capacity Assessment Surveys.

Rangeland		1974 Survey	1976 Survey	Test 1	Test 2	Sites >60% 1974	Sites >60% 1976
Open Woodland	$\bar{x}$	45.3	53.4	N.S.	N.S.	16%	50%
	s	±13.5	±18.7				
	CV	30%	35%				
	n	25	16				
Mitchell Grass	$\bar{x}$	62.9	54.1	N.S.	N.S.	66%	36%
	s	±17.3	±22.9				
	CV	27%	42%				
	n	15	11				
Mulga-annual Understorey	$\bar{x}$	52.9	66.1	N.S.	N.S.	43%	66%
	s	±19.1	±14.5				
	CV	36%	22%				
	n	7	15				
Mulga-perennial Understorey	$\bar{x}$	63.0	67.9	N.S.	N.S.	58%	86%
	s	±17.6	±11.1				
	CV	28%	16%				
	n	12	7				
Cottonbush Floodout	$\bar{x}$	24.0	35	N.S.	N.S.	0%	0%
	s	±6.4	8.6				
	CV	27%	25%				
	n	6	3				
TOTAL - all rangelands, all sites	$\bar{x}$	51.5	58.1	-	N.S.	36%	53%
	s	±19.1	±18.9				
	CV	37%	33%				
	n	65	52				

Test 1 = Wilcoxon Matched - Pairs Signed-Ranks Test
Test 2 = Students "t" Test.

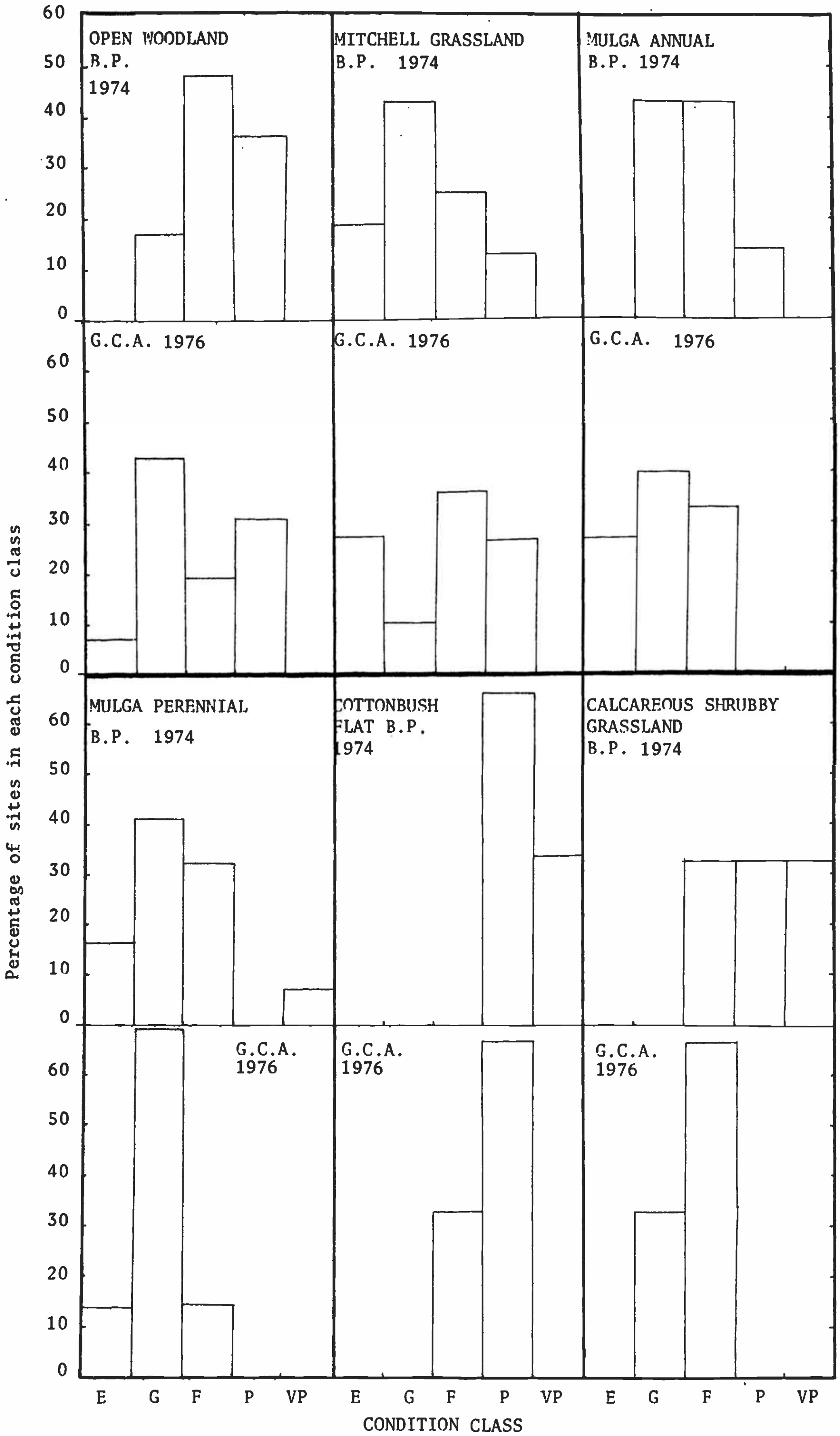
TABLE 2

The relationship between STARC score and distance from watering point (km) for the 1974 Burt Plain and 1976 Grazing Capacity Assessment Surveys.

Survey	Rangeland Type	Corr. Coeff.	F Test	Sig. of Reg.	Regression Equation
B.P.	All types & all sites	.10	.59	N.S.	-
	Open Woodland	.18	.79	N.S.	-
	Mitchell Grass	-.25	.89	N.S.	-
	Mulga-annual Understorey	.12	.06	N.S.	-
	Mulga-perennial Understorey	.27	.79	N.S.	-
	Cottonbush Floodout	-.19	.17	N.S.	-
G.C.A.	All types and all sites	.26	3.68	N.S.	-
	Open Woodland	.52	5.14	*	STARC=29.2 + 8.0 (km).
	Mitchell Grass	.21	.43	N.S.	-
	Mulga-annual under-storey	.34	1.68	N.S.	-
	Mulga-perennial Understorey	-.72	5.33	N.S.	-
	Cottonbush Flood-out	-.95*	8.33	N.S.	-

N.S. Not Significent at 5% or 1% level.

* Significent at 5% level.



E=Excellent 80-100; G=Good 60-79; F=Fair 40-59; P=Poor 20-39; VP=Very Poor 0-19.

Fig. 1

Percentage distribution of assessment sites into condition classes for six rangeland types in the 1974 Burt Plain (B.P.) Survey and the 1976 Grazing Capacity Assessment Survey (G.C.A.).

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Survey of paddock size and stock water supplies in the western Riverina district of New South Wales

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Abstract

In order to assess the current level of stock watering facilities on pastoral properties within the western Riverina, and to relate this information to paddock size and vegetation type, large areas of land (785,000 ha) within the region were surveyed. Paddock boundaries and the location of watering points were plotted. Watering points were classified as to type.

Mean size of paddocks was related to vegetation type. On the degraded grasslands in the eastern part of the study area the mean paddock size was 746 ha. Paddock size in the chenopod shrublands averaged 780 ha. In the Mallee-dominated areas mean paddock size was 1,553 ha.

The number of permanent watering points per paddock varied from one to four. Less than half the paddocks (43%) had fresh water available as an alternative to the saline ground waters generally available from sub-artesian bores.

Almost half the paddocks (47%) were sufficiently large, or the watering points so positioned, that the sheep would need to walk 3km or more to reach the most remote part of the paddock at seasons of the year when temporary waters had dried up. Overall 18% of the land in the non-mallee areas lay beyond a 3 km radius of permanent water.

The management implications are discussed.

I. INTRODUCTION

Livestock grazing is the principal form of land use over much of the semi-arid western Riverina in south-west N.S.W. (Leigh and Noble, 1972). Knowledge of the conditions under which livestock are raised commercially is a prerequisite to the study of management options. Management is often severely constrained by the location of fences and watering points.

The relationship of paddock size to watering point distribution has been shown (Squires and Hindley, 1970) to be an important one. The ability of sheep to walk long distances to water has been assessed (Squires, Wilson and Daws, 1972) and it can be concluded that land lying beyond a radius of about 3 km from water is likely to be outside the range of sheep grazing a saline pasture such as saltbush in summer (Squires, 1976).

As part of any overall inventory of rangeland resources in western N.S.W. we need to know the size of paddocks, the distance between watering points, the proportion of each paddock (expressed as a percentage of the total paddock area) effectively served by watering points, and the permanency of water points. Furthermore we need to assess the influence of vegetation type on these factors.

The aim of the work reported here was to assess the current level of stock watering facilities on pastoral properties within the western Riverina and to relate this information to paddock size and vegetation type.

II. METHOD

Location

The survey area included part of the Riverine Plain. In broad terms the vegetation formations (Figure 1) progress from dry sclerophyll forest at the eastern margin through savannah woodland to shrub steppe and mallee in the west (Leigh and Noble, 1972).

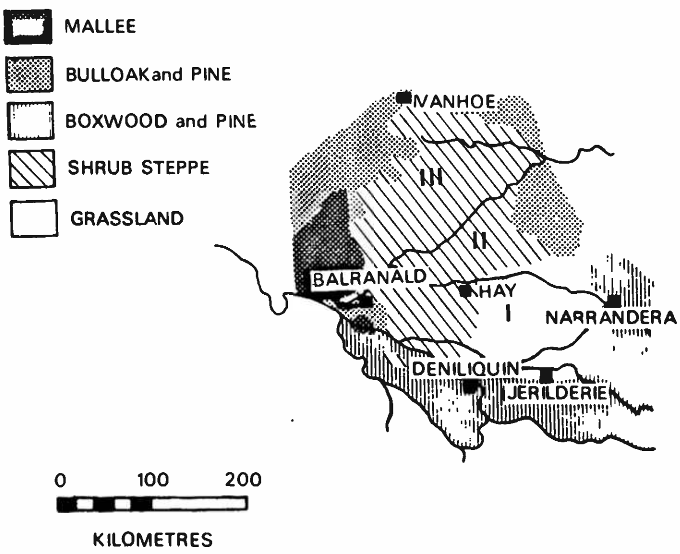

Figure 1. Locality map showing the survey area and Zones I, II and III. The broad pattern of vegetation is indicated.

The survey was limited to properties north and west of Deniliquin where irrigation development was not a complicating factor and where there was no river frontage. Three zones were recognised within the survey area (Figure 1). The area between the Billabong Creek and the Murrumbidgee River was designated Zone 1 and was the subject of an earlier survey reported by Squires and Hindley (1970). Zone II includes the area between the Murrumbidgee and the Lachlan Rivers and Zone III is the land lying north of the Lachlan River within the boundaries of the Balranald Shire.

Procedure

Two separate procedures were employed to collect information on paddock size and location of watering points. In the area between the Murrumbidgee and the Lachlan rivers (Zone II in Fig. 1) the survey depended on a combination of aerial photo interpretation and spot checks for ground truth along a transect. A technique involving the use of small scale (1:30,000) aerial photography was developed (Squires and Hindley, 1971). Aerial photographs were obtained on loan from the N.S.W. Department of Lands and paddock boundaries were traced from them. The watering points were located and classified as to type. Two principal types of water developments were recognised a) excavated ground tanks and b) sub-artesian bores. In some paddocks there were wells.

For land lying north-west of the Lachlan river (Zone III in Fig. 1) a postal questionnaire was conducted. A copy of their property outlines (drawn to scale) was sent to 180 land holders along with a request that they fill in the paddock boundaries and show the location of each watering point. A questionnaire was enclosed and additional information on vegetation, water quality, and permanency of surface waters was sought.

The major parameters considered were paddock size, number of watering points per paddock, position of watering points, area of land lying within a 3 km radius of a watering point, maximum distance from water in any given paddock, salinity of bore waters,permanency of ground tanks, and dominant vegetation type in each paddock.

III RESULTS

Zone 1

The results from this zone were presented in detail in Squires and Hindley (1970) but are summarized here for the convenience of the reader. Mean paddock size was 883 ha with a modal size of 708 ha. Over 48% of the total land area surveyed (100,000 ha) lay beyond a 2.4 km radius of permanent water while the maximum distance to water exceeded 3.2 km in 45.4% of the 114 paddocks surveyed.

Zone 11

The area between the Murrumbidgee and the Lachlan rivers is made up of two major vegetation alliances (Leigh and Noble, 1972). The Eastern section which extends from a point just west of Narranderra to a line approximately defined by the Cobb Highway linking Deniliquin and Hay (see fig. 1) is predominantly a disclimax community in which the principal species are the perennial grasses Danthonia caespitosa (white top) and Stipa variabilis (variable spear grass). The area west of the highway and extending to Balranald is an Atriplex vesicaria (bladder saltbush) alliance. The results for each region were analysed separately.

Eastern region: Paddocks of less than 100 ha in area were not included in the analysis. These paddocks were generally holding areas associated with stock yards, shearing sheds or homesteads. Of the remainder, 102 paddocks were analysed. The mean paddock size was 746 ha (range 125-3470 ha) with a modal size of 671ha. The maximum number of watering points (bores or large excavated tanks) in each paddock was four, although several small excavated tanks provided water in the cooler months (June-October). The most common position was in the corners of paddocks (so that each served more than one paddock) or at sites along the fencelines at the midpoint of paddocks. Most ground tanks in this region are 'permanent' because run-off water is supplemented in many areas by irrigation drainage waters which are derived from the nearby Murrumbidgee Irrigation Area and other local irrigation schemes.

Bore water salinity was tested from 10 bores within the region as part of the ground truth collection. Salinities ranged from 0.2% to 0.7% total soluble salts. It was uncommon for bore water to be the only source of water in a paddock. Over half (54%) of the paddocks had fresh water available all or almost all of the year.

The maximum distance from the watering point to the most remote part of the paddock exceeded 3 km in only eight of the paddocks surveyed while in three paddocks the distance exceeded 4km. On average only 10.7% of the land area lay beyond a 3 km radius of water.

Western region: Excluding the small paddocks of $<$100 ha there were 223 with an average size of 780 ha (range 103-2845 ha). The modal size was 673 ha. The average number of watering points per paddock was only two in this region and a higher proportion of them were bores. Again the placement was either in a corner or on the midline of a subdivision fence.

Fewer paddocks (37%) provided alternative fresh water sources than in the eastern region. Ground tanks were generally larger with many exceeding 10,000 m^3 in capacity. Water from drainage of irrigation areas was not available and many tanks did not provide water on a year-long basis unless capacity was in excess of about 10,000 m^3.

The maximum distance from the wateringpoint to the most remote part of the paddock was 3 km in 41 of the paddocks and $>$4 km in 21 of them. On an area basis, 27.8% of the land lay outside a 3 km radius of water.

Zone III

Almost all of the land surveyed in this zone is within the boundaries of the Balranald Shire.

Vegetation within the Zone III was more variable than in other Zones. In the eastern region the predominant vegetation was *A. vesicaria* while in some localised areas bluebush (*Maireana pyramidata*) was dominant. On the north and west margins of the Zone mallee (*Eucalyptus oleosa*, *E. dumosa*) predominated. Because of the information supplied by the landholders on a paddock by paddock basis I was able to derive a relationship between vegetation type and paddock size in Zone III. In general paddocks were larger in Zone III irrespective of vegetation type but paddocks within the mallee-dominated areas were larger (1230-6800 ha) than those dominated by chenopods (374-1276 ha). Of the 286 paddocks surveyed in Zone III the mean size was 1553 ha (range 374-7760 ha) with a modal size of 1847 ha.

There were marked differences in the number of watering points per paddock in the mallee areas of the Zone and those areas dominated by chenopods. On average each paddock in the saltbush areas had 3.5 waters while in the bluebush dominated areas there were two. Mallee areas usually only had one and quite commonly it was an excavated tank of large capacity. There were more small-capacity (temporary) water points among the gently undulating mallee areas but the sandy soils and the poor water holding capacity of the subsoils made long term storage difficult.

The maximum distance to water in a paddock was a variable parameter. In the chenopod-dominated areas the distance was $>$ 3 km in only a few (12.7%) paddocks and, on an area basis, this represented 17.4% of the total land area. Distances to 'permanent' water in mallee-areas exceeded 7 km in 42% of paddocks. It seems clear that temporary waters provided livestock access to these paddocks on a seasonal basis only.

Information on bore water salinity, as supplied by the landholders, shows that in general the deeper bores had better quality water and that salinity increased to the west. In the mallee areas subartesian bores are less common and more reliance is placed on excavated tanks. Here sandy soils of high permeability create problems for siting tanks and the most successful tanks are those on a rocky bottom or where crystalline gypsum outcrops occur. Many (32%) paddocks were not supplied with permanent water and livestock grazing is confined to the cooler months when surface water is available in temporary storages and when stock water demands are low.

There were 169 watering points in Zone III of which 106 (62%) were ground tanks, 43 (25.4%) were bores, and 21 (12.5%) were wells. Ground tanks varied in size from 2500 m^3 to about 40,000 m^3. The modal size was in the range 5000-7000 m^3. The 43 bores varied considerably in depth from $<$ 15 m to $>$ 140 m with a modal value of 45 m The deepest bore was 233 m. For the 23 bores in which depth to water was known, the modal value was 6-7 m (range 4.9-31.6m). Wells were generally shallow (12-15 m) although four wells were $>$ 33 m deep. Most watering points were established $>$ 30 years before the survey began. No new wells have been dug since 1914.

IV. DISCUSSION AND CONCLUSIONS

The survey involved 612 individual paddocks and covered an area of 785,418 ha. Property size, among those properties surveyed, ranged from 3127 to 42817 ha. The mean size was 12578 ha. The average number of paddocks per property was 7.1 (range 2-13). Paddocks of 100 ha are not considered in this assessment. By comparison with the central Riverine Plain (Zone 1, Fig. 1) surveyed earlier by Squires and Hindley (1970), the northern Riverine Plain has fewer watering facilities. Almost half of the paddocks (47%) were sufficiently large, or the watering points were so positioned, that sheep would need to walk 3 km or more to reach the most remote part of the paddock at seasons of the year when temporary waters had dried up.

Overall only 18.6% of the land within Zone II lay beyond a 3 km radius of permanent water. The figure was similar for the chenopod areas of Zone III. The mallee areas (off the Riverine Plain) were less well served by permanent waters and the proportion of land lying beyond a 3 km radius was in excess of 35%.

Information on bore water salinity was derived from a number of sources, including previously published information. These results indicated that much of the water was close to the salinity limit which is tolerable for sheep grazing saltbush dominated pastures (Wilson, 1975). The tendency for salinity to increase from east to west which was first reported by Jones, Leigh and Mulham (1968) is supported by the results from this survey. Less than half of the paddocks (43%) had fresh water available as an alternative to the saline ground waters and of these not all were available on a year-long basis.

Paddock size was generally similar in both Zones I and II and in the non-mallee areas of Zone III. Paddock size once determined is not easily altered. Unless a fire removes a fence the next unit of subdivision is to split the paddock in half. This may provide a second best approximation to optimum paddock size given the objective of maximum pasture utilization. Subdivision allows greater control of livestock, but also decreases the size of the management unit which increases costs. Better utilization of pastures via subdivision would normally require additional water points. These additional costs must be offset by the increased returns which would result from better management and greater utilization. The relationship between paddock size and vegetation type noted in Zone III suggests that these trade offs are very real considerations to the grazier, as he tries to balance pasture productivity, carrying capacity and flock size.

Information on the optimum spacing of wateringpoints has come from studies of sheep behaviour (Squires, Wilson and Daws, 1972; Squires, 1976) which suggest that the grazing range of sheep is dependent on breed, age, and physiological status of the sheep and the type of pasture on which they are confined. For Merino sheep on saltbush drinking once daily a grazing range of 7 km might be reasonable. In the light of this survey, where only 18% of the land lay beyond a 3 km radius of permanent water, the majority of the land area could be used in all seasons. In wet years the additional 18% could be utilized. It is likely though that some sheep would reduce drinking frequency to less than once daily (Squires and Wilson, 1971) and could utilize the far reaches of the paddocks in all but the driest seasons.

We might conclude then that the region is adequately watered. It is unlikely to be economic to supply permanent waters to the mallee country. In some paddocks where there is a large proportion beyond a 3 km radius of water extra water points might be justified but there is clear need to cost it out in the light of the behavioural considerations outlined above.

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The determination of an optimum sampling technique for biomass of herbaceous vegetation in a Central Australian woodland

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Abstract

The green standing material, dry standing material and litter in the herbaceous layer of a Central Australian woodland were sampled using sets of nested quadrats of various proportions.

By minimising the product of the time required to obtain the data and the relative variances of the mean weights of material, the optimum size of quadrat necessary for estimating biomass was found to be 1 square metre or less. The optimum shape was 1:16 for litter but there was no preferred shape for green or dry material in this case.

No edge effect was detected.

A method is given for determining the optimum number of quadrats for a known mean, variance and cost.

Introduction

An important requirement of any vegetation study is a suitable sampling technique. Most techniques for estimating biomass have been evolved in temperate climates and they may not be appropriate in arid environments. The distribution of arid zone vegetation can be highly irregular and sparse, so that the size and number of quadrats required for a representative sample may need to be greater than in temperate or tropical climates. In addition, the conventional square quadrat may not be appropriate.

A quadrat of 1 square metre or less is commonly used in temperate climates for sampling herbaceous species e.g. Wiegert and Evans (1964) and for sampling litter e.g. Gosz et al. (1973). Bray et al. (1959) used larger quadrats for some sampling but the dominant herbaceous species were up to 3 metres high. On the other hand, Pechanec and Stewart (1940) recommended sampling subunits of 50 square feet in sagebrush - grass range in Idaho, and that these units be circular.

A square quadrat has been the most consistently used shape in vegetation studies, while a circular shape is the most efficient for reducing the 'edge effect'. The edge effect is the bias which arises when vegetation is being clipped along the edge of a quadrat and the worker must choose what to include or exclude. The elongate rectangle has been found to be most efficient in incorporating maximum variation within quadrats and ensuring minimum variation between quadrats (Christidis 1931, Jain 1967). The limit to the elongate shape is the increasing error of the edge effect.

The number of quadrats used in sampling has an upper limit set by the time available for the work. Since the variance of the mean is inversely proportional to the number of quadrats required to determine it, the lower limit is set by the amount of error that can be tolerated.

This work is an attempt to optimise the size, shape and number of quadrats necessary for future studies of productivity in Central Australian woodlands. The optimum quadrat size and shape were determined by compromise between the variance of the mean weight of collected material and the cost, measured in terms of time. These calculations were made for three categories of vegetation: green standing material, dry standing material and litter. The optimum number of quadrats could be calculated from the variance of the mean of the best sized and shaped quadrat and the acceptable level of error, which is also limited by time.

The Study Area

In the Central Australian rangelands, a number of different vegetation associations (range eco-units) can be delineated and several of these are important to the pastoral industry. The open woodland eco-unit in which this study is based consists of scattered trees (*Atalaya hemiglauca*, *Acacia aneura*, *A. kempeana*, *A. estrophiolata*, *Hakea suberea*), scattered shrubs (*Eremophila spp.*, *Cassia spp.*) and ground cover of low-growing forbs and grasses, predominantly *Aristida contorta* and *Enneapogon* spp., which are a source of forage for cattle. Annual rainfall averages 250 mm. but has been above 500 m. for 1973-1975.

Methods

Field sites were selected subjectively on the basis of species composition typical of open woodland. Sites were not placed close to trees because the area of vegetation subject to their influence was only a small proportion of the whole. Four sites within a radius of 1 km. of a marker post were chosen and four randomly selected replicates of the required material was collected at each site within an area of ¼ hectare, giving a total of sixteen replicates.

At every sampling position, three sets of three nested quadrats were laid out as in Fig. 1 (a), (b), and (c). By addition, the possible number of quadrat sizes was seven in each set, with relative areas as follows:-
1 (0.25 sq.m.),
3 (0.75 sq.m.),
4 (1.00 sq.m.),
12 (3.00 sq.m.),
13 (3.25 sq.m.),
15 (3.75 sq.m.),
16 (4.00 sq.m.)
Sizes 1,3,4,12 and 16 were used (Wiegert 1962). Altogether, sixteen replicates of the three sets of quadrats were made as this number was thought to be more than sufficient for any future work with a limit on time.

Each of the nested quadrats was clipped separately, and the litter was collected separately from each. The material was oven dried at 80°C and, after separation of the clipped samples into green and dry components on the basis of whether they were green coloured or not, the three categories of vegetation (green standing, dry standing and litter) were weighed. The time taken for each part of the operation was recorded.

Results and Discussion

The mean weight and variance per square metre of the mean weight of each category of vegetation for each quadrat size and shape and the mean time taken for processing, or cost, is presented in Table 1.

Wiegert (1962) proposed that "the cost of a single quadrat.....consists of a fixed cost, c_f, which is independent of the size of the quadrat (walking between stations, weighing etc.) plus x times a cost, c_v, which is the time spent clipping and sorting a quadrat of size 1". 'x' is the quadrat size. He estimated the relative cost $C_r = (c_f + xc_v) / (c_f + c_v)$, for the various quadrat sizes and proposed that the optimum quadrat size be chosen by minimising $C_r . V_r$, where V_r is the relative variance of the mean. He apparently did not test for statistically significant differences between the various values of $C_r . V_r$.

In the data reported here, c_f was such a small proportion of the total cost that it was included in a single cost measurement 't' and variance was simply expressed per square metre 'V'. The optimum quadrat size and shape was chosen by minimising t.V. Tests showed correlation of t and V at the 0.1 level of probability in only three out of twenty-seven sets of comparisons. This was taken to be an ade-

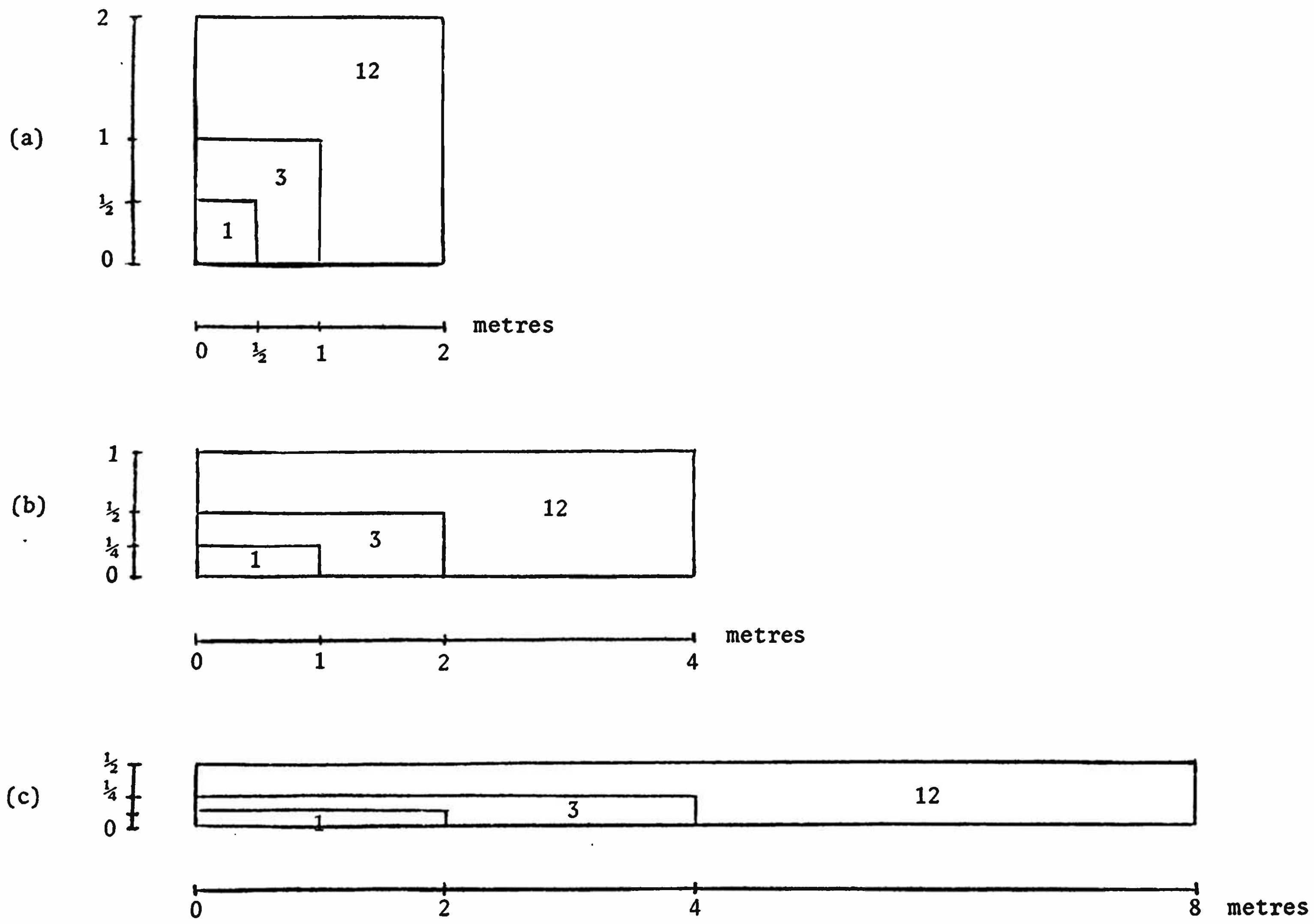

FIGURE 1. The arrangement of each of the three sets of quadrats (a), (b) and (c). Area 1 is 0.25 square metres, area 3 is 0.75 square metres and area 12 is 3.00 square metres in each set. The ratios of the lengths of the quadrat sides are (a) 1:1, (b) 1:4 and (c) 1:16.

QUADRAT		GREEN			DRY			LITTER		
Shape	Size (m^2)	Mean weight (g./sq.m.)	Variance of mean weight (per sq.m.)	Mean time (min.)	Mean weight (g./sq.m.)	Variance of mean weight (per sq.m.)	Mean time (min.)	Mean weight (g./sq.m.)	Variance of mean weight (per sq.m.)	Mean time (min.)
1:1	1(0.25)	27.6	272	47	153	6480	47	73.6	3584	8
	3(0.75)	31.2	126	102	146	2741	102	60.7	1568	11
	4(1.00)	30.3	88	149	148	2155	149	64.0	1757	12
	12(3.00)	27.3	94	415	149	523	415	60.8	718	20
	16(4.00)	28.0	81	562	149	668	562	61.6	831	23
1:4	1(0.25)	22.8	160	35	124	2080	35	64.8	1984	8
	3(0.75)	31.2	325	113	151	1579	113	74.9	1998	12
	4(1.00)	29.1	241	148	146	1471	148	72.5	1898	13
	12(3.00)	26.4	61	418	157	1247	418	53.4	524	18
	16(4.00)	27.1	75	566	154	1115	566	58.2	541	22
1:16	1(0.25)	26.8	336	40	144	5184	40	48.0	416	8
	3(0.75)	27.7	211	115	153	1520	115	57.7	693	12
	4(1.00)	27.5	148	155	151	1656	155	55.3	475	12
	12(3.00)	39.6*	1537*	394	143	1495	394	60.8	344	19
	16(4.00)	36.6*	864*	549	145	1241	549	59.4	276	22

* These values are excessively high due to the erroneous inclusion of a large woody - stemmed Composite.

TABLE 1. The mean weight per square metre, variance per square metre of the mean weight (V) and mean time taken for processing, or cost, (t), for green standing material, dry standing material and litter.

quate indication that t and V were in fact not correlated and hence that minimising t.V was legitimate.

The product t.V represents the variance which would be expected for a sample which took unit time to collect and therefore amounts to an estimate of variance. A variance ratio test for significant difference is consequently appropriate. Assuming that the distribution of the ratio of two t.V products, i.e. $(t_x.V_x) / (t_y.V_y)$, is log normally distributed, an approximate test for a significant difference took the form:

$$\ln (t_x.V_x) - \ln (t_y.V_y)$$

which is equivalent to ln (F/2). If the difference exceeded 2.04, it was significant at the .05 level of probability.

The values of ln t.V are given in Table 2. The only significant differences within the one shape class are between size 1 and size 16 for dry standing material from quadrat shape 1:4 and between size 1 and sizes 12 and 16 for green standing material from quadrat shape 1:16. The latter difference is due however to an artificially high value of V for sizes 12 and 16 (see footnote Table 1) and must be discounted. The only significant differences within the one size class are between quadrat shape 1:1 and shape 1:16 for litter from a quadrat of size 1 and between quadrat shapes 1:1 and 1:4 and shape 1:16 for green standing material from quadrats of both size 12 and size 16. The differences for green standing material are due to the same artifact mentioned above and should also be discounted.

QUADRAT		GREEN	DRY	LITTER
Shape	Size ($m.^2$)		ln (t.V)	
1:1	1(0.25)	9.46	12.63	10.26
	3(0.75)	9.46	12.54	9.76
	4(1.00)	9.48	12.68	9.96
	12(3.00)	10.57	12.29	9.57
	16(4.00)	10.73	12.84	9.65
1:4	1(0.25)	8.63	11.20	9.67
	3(0.75)	10.51	12.09	10.09
	4(1.00)	10.48	12.29	10.11
	12(3.00)	10.15	13.16	9.15
	16(4.00)	10.66	13.36	9.38
1:16	1(0.25)	9.51	12.24	8.11
	3(0.75)	10.10	12.07	9.03
	4(1.00)	10.04	12.46	8.65
	12(3.00)	13.31*	13.29	8.79
	16(4.00)	13.07*	13.43	8.71

* See footnote table 1.

TABLE 2. The natural logarithm of t.V, where t is the mean time (min.) taken for processing, or cost, and V is the variance of the mean weight (per sq.m.) for green standing material, dry standing material and litter. Differences of 2.04 or more between values indicate a significant difference at the .05 level of probability.

The results suggest that a small sized quadrat may be preferable and that an elongate shape of quadrat is advantageous for litter but unimportant for green or dry standing material. When vegetation is homogeneous, a square quadrat satisfactorily encompasses its pattern of distribution, if the quadrat is an adequate size. But when the vegetation is heterogeneous, an elongate shape of quadrat will incorporate the variability far better. The pattern of distribution is complex in arid vegetation and, coupled with increasing total variance as sampling area is increased, a continuum of vegetational change is likely (Goodall 1961). It was thus expected that the elongate shape would confer some advantage but it did so for litter only. An analysis of variance did not detect any significant difference between mean weights of each category of vegetation for quadrats of the same area but of different shape. The absence of bias shows that there was no edge effect.

Small quadrat size was expected to be preferable because statistically the smaller the sampling unit, the more efficient it is per unit area (Pechanec and Stewart 1940). The trend of results indicates that this may be so for green and dry standing material but that for litter, the quadrat size is not important.

The number of quadrats selected depends on the nature of the work in which they will be used. The calculation takes this form:

$$n = \frac{4\sigma^2}{L^2}$$

where n is the number of quadrats, σ^2 is the variance and L is the allowable error in the sample mean with a 5% chance that the error will exceed L (Snedecor 1957). Almost invariably, the time taken to process the number of quadrats will limit the value to which L can be reduced.

The results presented here suggest that, for the area sampled, the quadrat chosen would be of 1 square metre or less and of a shape that was most convenient to the user. A quadrat of considerably less that 1 square metre may not be desirable on other grounds not considered here, for instance for financial reasons, since the smaller the quadrat the greater the number of quadrats required to compensate for increased variance per unit area, and hence the greater the cost of markers.

Acknowledgements

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Some techniques used in the investigation of habitat utilization by red kangaroos in North-western New South Wales.

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Brisbane.

The problems confronting those concerned with the management of wildlife, particularly the larger species of wildlife such as kangaroos, are similar to the problems of those involved in range management. Both groups wish to know the potential stocking rate of an area and the number and condition of the animals presently in that area. In Australia, because of competition between large wildlife species and their domesticated counterparts, it is desirable that decisions concerning the density and variety of animal species within an area are made in the light of information that is easily and rapidly available. The information required before making any decisions involves the number and condition of a native species that is occupying an area and the amount and quality of food available to that species within the area.

Information of food availability is required to estimate stocking rate, whilst the observed stocking rate, i.e. density of animals can be contrasted to this estimated value. Finally, information on the condition of the animals allows a picture to be drawn of the use being made by an animal of an area and the potential that area may have for different stocking rates in the future. These predictive models are the type of approach which National Parks and Wildlife authorities must nowadays be making when decisions are made concerning the setting aside of land for the conservation of wildlife or in decisions concerning the multiple use of land by different groups of people.

Body condition is usually measured in terms of body weight, although in animals which store quantities of fat, measurements of specific parts of the body, e.g. tail butt circumference in marsupial mice or skin thickness in pigs are used. In kangaroos, fat storage is low, the proportion of body fat to total body weight is about 2% (Tribe and Peel, 1963). Variations in this amount of fat would be difficult to measure, consequently body weight is the main criteria used to estimate body condition in kangaroos.

Measurements of body weight alone will not give reliable estimates for inter and intraspecific comparison and these measurements must be related to some other body measurement which does not change with variations due to nutrition, breeding condition, season etc. Many studies use age as the other criterion. However, in kangaroos, age is difficult to estimate in the field, particularly on live animals. Measurements of various bone lengths or organ weights are reliable criteria which can be measured from carcases.

Once a relationship has been established for animals in good condition (this can be judged from other observations) then any deviation from this relationship will indicate a change in body condition. In this study a relationship for red kangaroos in good condition was developed from data taken from a group of red kangaroos shot during 1975. All animals were male and their full weights ranged from 32 to 91 kg (mean 57 kg). The weights of the following were measured; full carcase, dressed carcase, gastrointestinal tract plus contents, liver, heart, kidney and tail. Linear measurements were fore-arm length, pelvis width, hind-foot length and forearm circumference. In Table I are the relationships established between full body weight and the other measurements. These relationships are presented as linear regressions. Relationships also exist between dressed carcase weight and the other measurements and would be useful when information can be obtained from a kangaroo boning works.

Obviously for live caught animals, only linear measurements are used. Foot length ($r=0.28$ for dressed carcase weight versus foot length) was too variable to be used reliably and fore-arm circumference shows marked sexual dimorphism (the circumference of the fore-arm of male red kangaroos increases rapidly during the period of sexual maturation). However, pelvic width, fore-arm length and tail butt circumference can be used to give reliable estimates of body condition. Another relationship developed since 1975 is between full body weight and crus length (distance from foot to approximate top of tibia). This also gives reliable estimates of body condition (r=0.898, crus length=0.36 full weight + 37.5, n=227).

It was important to test the efficiency of assessing body condition by this method. It was found to be impossible to place an arbitrary statistical level ona series of values and attempt to draw functional conclusions from any deviation from this level. In an investigation into the effects of water deprivation on various physiological parameters of red kangaroos, animals were placed in cages and deprived of water until their body weights reached 80% of their original value (Denny and Dawson, 1975). Although the animals appeared emaciated, when the values for body weights were plotted on a graph showing the relationship between body weight and fore-arm length (figure 1) it was found that even after 20% of the body weight is lost the body weights do not fall outside the 95% confidence limits calculated for the regression.

However, by using a chi-squared test to find any difference between observed body weight and that calculated from the appropriate bone length regression equation, a useable technique has been established. The results of two examples involving the use of the chi-squared test are given in Table II. The first set of data was taken from red kangaroos shot at Fowler's Gap Station during a minor drought in 1967 and the second set of data from a group of grey kangaroos found marooned upon an island in Burrendong Dam, near Wellington in 1977. The results of the test show that both groups of kangaroos were in poor body condition when compared with animals known to be in good condition in 1975. Even more subtle changes in body condition can be detected by using linear measurement-body weight relationships. Groups of red kangaroos live caught within Sturt National Park, Tibooburra during 1975 and 1976 have shown an increase in body weight (38.0±1.52 kg (226) in 1975 and 47.5±1.27 kg (230) in 1976, $P < 0.001$) but there was no obvious sign of better body condition in those animals caught in 1976(one may have just caught larger sized animals in

1976). However, if the relationships between fore-arm length and body weight are plotted for each year, a series of lines eventuates which shows that same-sized kangaroos caught in 1976 were heavier than when caught in 1975 (see figure 2). Towards the 60 kg body weight value the three plotted lines converge. This convergence is consistent with the data presented by Frith and Calaby (1969) from a series of shot animals where it was found that a male kangaroo's growth rate tapers off after 60 kg.

Range condition can be defined in terms of the potential a particular area has of sustaining a certain stocking rate and any estimate of range condition usually requires a relatively full knowledge of the floral species within the area by the researcher. However, many people involved in wildlife management have not had suffieient botanical training to be competent in such an assessment. Also, the time taken to build up a plant inventory can be great and many of the decisions in wildlife management must be made relatively quickly because of external pressures, political and otherwise.

Consequently a method was developed to evaluate range condition which relied entirely upon measurements of the quantity and quality of vegetation within an area, and not upon taxonomy. Samples of vegetation were measured in an area by means of $\frac{1}{4}m^2$ plots. Within a relatively uniform area 8 samples were taken, however in other areas, particularly where rapid changes were occurring, e.g. after fire, then up to 100 sample plots were measured.

Within each $\frac{1}{4}m^2$ plot the vegetation was divided into grasses and forbs and three measurements were taken of each floral group. The measurements were plant height, plant density (as percentage cover) and plant greenness. Plant greenness is a subjective assessment ranking the greenness of plants from 1 to 5. Rank number one represents a completely dry plant, number two represents a plant with a green base, number three represents a plant with green on the stem, number four represents a plant that is green all over and number five represents a plant recently eaten by the animal studied (figure 3). Once the investigator has been shown examples of each rank, it is usually easy for comparable results to be obtained.

Because of the relative uniformity of the vegetation within each $\frac{1}{4}m^2$ plot, it is usual for plants to be even in height and greenness throughout the plot. However, if this does not occur it is simple enough to divide the vegetation into further categories such as tall and short grasses etc and measure each category accordingly. Plant density is measured in units of 5% unless density is less than 5%, in which case 1% units are used. The number five rank is difficult to use outside a national park where there is grazing competition with kangaroos from sheep and cattle.

Also included within the inventory are tree height, tree density, tree shelter (number of trees used recently by kangaroos recently for shade), shrub height, shrub density and shrub shelter. The division between trees and shrubs was one of height (up to 2m for shrubs) although one tended to place different species into one category or the other, e.g. Eromophilia (sp), Cassia (sp) were classed as shrubs and mulga and whitewood species as trees.

This method allows one to assess an area and relate it to the numbers of animals occupying that area. For instance, a study of movements of red kangaroos within the Tibooburra region has used this method of range condition assessment to explain why these animals are in a certain area at a certain time. Densities of kangaroos were estimated along certain transects inside and outside Sturt National Park and it was found that these densities change significantly from one land system to another, and even within a single land system. Many of these differences in utilization of an area by kangaroos can be explained by such parameters as nearness to water and shelter. However, many of the patterns of kangaroo distribution can be related to differences in the vegetation characteristics within the area. For instance, within a particular land system the areas along one particular creek were found to contain greener and more dense grass than beside another creek. Kangaroo numbers were higher near the creek with the greener and more dense grass.

There also appears to be a relationship between those parameters used to describe range condition as outlined above and the parameters used to estimate primary productivity of an area. Such parameters are plant biomass (wet and dry), plant water content and total digestible nitrogen. Biomass (both wet and dry) and plant water content have been estimated for several areas in the Tibooburra region and the results compared to plant height, density and greenness. There appears to be a relationship between biomass and plant volume (plant height times density) and between plant water content and plant greenness (see figures 3 and 4). Both give regression co-efficients which indicate a close relationship between the parameters measured. However it must be stressed that the sample sizes are still much too small to use these relationships with confidence and more reliable relationships await further results. One example where the similarities between the different parameters measured became apparent was during an experimental burn on Sturt National Park. Range condition was assessed both before and after the fire and both methods of assessment were used, i.e. plant height, density and greenness was measured as well as plant biomass and water content. It was found that after the fire, grass and forb height and density fell whilst plant greenness rose. Similarly, the biomass of the grass and forbs fell after the fire whilst plant water content increased (Table III).

The final set of information required for wildlife management decisions is the number of animals within an area. Census of an animal population can be undertaken in many ways, all having their respective merits and faults. The three methods used in censusing kangaroo populations in north-western N.S.W. were ground and aerial counting and a capture-mark-release-recapture technique (C.M.R.R.).

Aerial censusing involved flying at a set speed (about 100 knots) and height (about 100 metres) and counting the number of animals seen within a set strip (approximately 200 metres) during the flight. Considerable discussion has surrounded this method of censusing animals (a workshop devoted entirely to aerial censusing methods was recently held in Canberra (Australian National Parks and Wildlife Service, 1977)). This method will give a value for population numbers relatively rapidly and, after appropriate adjustments, the value appears as accurate as that arrived at by any other method. However, the calibration of this technique is still difficult, particularly in regard to the sightability of animals in different habitats, and one does not always have a plane on hand to use for this form of census.

Censusing from a vehicle (ground counts) is more time consuming but would appear to give a more accurate estimate of population density than by aerial counting. It also allows the observer time to relate the animals seen to their immediate environment and gives an opportunity for the observer to undertake a range condition estimate at the same time.

Estimation of population numbers by use of a C.M.R.R. technique requires considerable setting up, particularly if kangaroos are concerned. The animals must be caught (either trapped or drugged), marked (e.g. collared) and released. A certain proportion of this marked population must be recaptured, shot or observed after an appropriate time. This method gives similar results as the above two methods (Table IV) but the time and equipment required restricts its use. Its advantage is that all animals captured are handled so that body condition estimates can be obtained.

The use of the techniques described above is still only tentative and the data obtained preliminary and one can still see room for improvement. Criticisms of each method can be made, for instance, it may only be possible to use the method for body condition assessment on animals weighing less than 60 kg and without plant taxonomy it will be difficult to relate range condition measurements to an animal's dietary habits. However, these faults are inherent in many other methods and will hopefully be eliminated as the methods improve.

As a rapid method of assessing an area these three techniques are extremely useful and, it is hoped, will be used in the future by people not only involved in the management of wildlife but also in the overall management of the Australian rangelands.

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Table I. Relationships between full body weight, bone lengths and organ weights of male red kangaroos, expressed as linear regression equations.
$y = a+bx$ where x = full weight (kg)

	Mean of X	Mean of Y	Intercept a	Slope b	Correlation Coefficient	Number of values
Liver weight (kg)	57.3	0.42	0.01	0.139	0.830	70
Heart weight (kg)	57.3	0.42	0.005	0.108	0.816	71
Kidney weight (kg)	56.6	0.87	1.23	17.82	0.873	30
Tail weight (kg)	57.3	3.82	0.07	-0.10	0.973	71
Pelvic width (cm)	56.6	21.99	0.18	11.69	0.85	47
Butt circumference (cm)	64.8	41.9	0.25	25.56	0.867	34
Forearm length (cm)	57.3	32.33	0.288	15.825	0.937	71
Forearm circumference(cm)	57.2	20.57	0.232	7.297	0.909	71

Table II. Differences between observed and predicted body weights of kangaroos in poor body condition.

A. Red kangaroos shot at Fowler's Gap Station in 1967.

Observed body weight (kg)	Expected body weight (kg)*	Significant difference using chi-squared test
30.1 ± 1.95 (50)+	38.8 ± 2.68 (50)	Sig. at 0.01%

B. Eastern Grey Kangaroos marooned in Burrendong Dam in 1977.

Observed body weight (kg)	Expected body weight (kg)	Significant difference using chi-squared test
(1) Female		
14.7 ± 1.48 (16)+	27.2 ± 4.08 (16)**	Sig. at 0.001%
(2) Male		
12.8 ± 3.34 (9)+	19.0 ± 5.16 (9)**	Sig. at 0.001%

\+ Means ± standard error (number of animals)

* Expected body weights calculated from relationship between crus length and body weight (see Table I)

** Calculated from data supplied by P. Hopwood

Table III. Characteristics of the vegetation within a grasslands plot.

A. Prior to Burning

(i) Range condition assessment

Grass height	48.1 ± 7.02	cms	(9)*
Grass density	39.4 ± 6.72	%	(9)
Grass greenness	3.2 ± 0.15		(9)
Forb height	11.9 ± 4.20	cms	(13)
Forb density	3.3 ± 0.92	%	(13)
Forb greenness	3.1 ± 0.36		(13)

(ii) Biomass measurements

Grass	wet weight	446.1 ± 102.03	g/m^2	(10)*
	dry weight	308.3 ± 76.05	g/m^2	(10)
	moisture	138.0 ± 27.67	g/m^2	(10)
	moisture	32.1 ± 1.89	%	(9)
Forb	wet weight	184.4 ± 30.67	g/m^2	(10)
	dry weight	81.8 ± 39.01	g/m^2	(10)
	moisture	102.7 ± 42.42	g/m^2	(10)
	moisture	68.1 ± 7.05	%	(9)

B. After Burning

(i) Range condition assessment

Grass height	14.3 ± 2.18	cms	(10)*
Grass density	5.6 ± 1.22	%	(10)
Grass greenness	3.8 ± 0.47		(10)
Forb height	4.3 ± 1.20	cms	(3)
Forb density	5.0 ± 2.65	%	(3)
Forb greenness	4.0 ± 0.00		(3)

(ii) Biomass measurements

Grass	wet weight	22.7 ± 5.72	g/m^2	(8)*
	dry weight	16.4 ± 4.48	g/m^2	(8)
	moisture	10.3 ± 2.05	g/m^2	(8)
	moisture	45.1 ± 3.90	%	(8)
Forbs	wet weight	6.9 ± 3.10	g/m^2	(3)
	dry weight	13.6 ± 13.20	g/m^2	(2)
	moisture	12.2 ± 11.80	g/m^2	(2)
	moisture	48.6 ± 13.8	%	(2)

* Means ± standard error (number of samples).

Table IV. Estimation of kangaroo population desnity within Sturt National Park during November 1976.

Estimation of population density by	Kangaroo density (kangaroos/km^2)
1. Aerial counting	8.01
2. Ground counting	8.77
3. C.M.R.R.	10.62

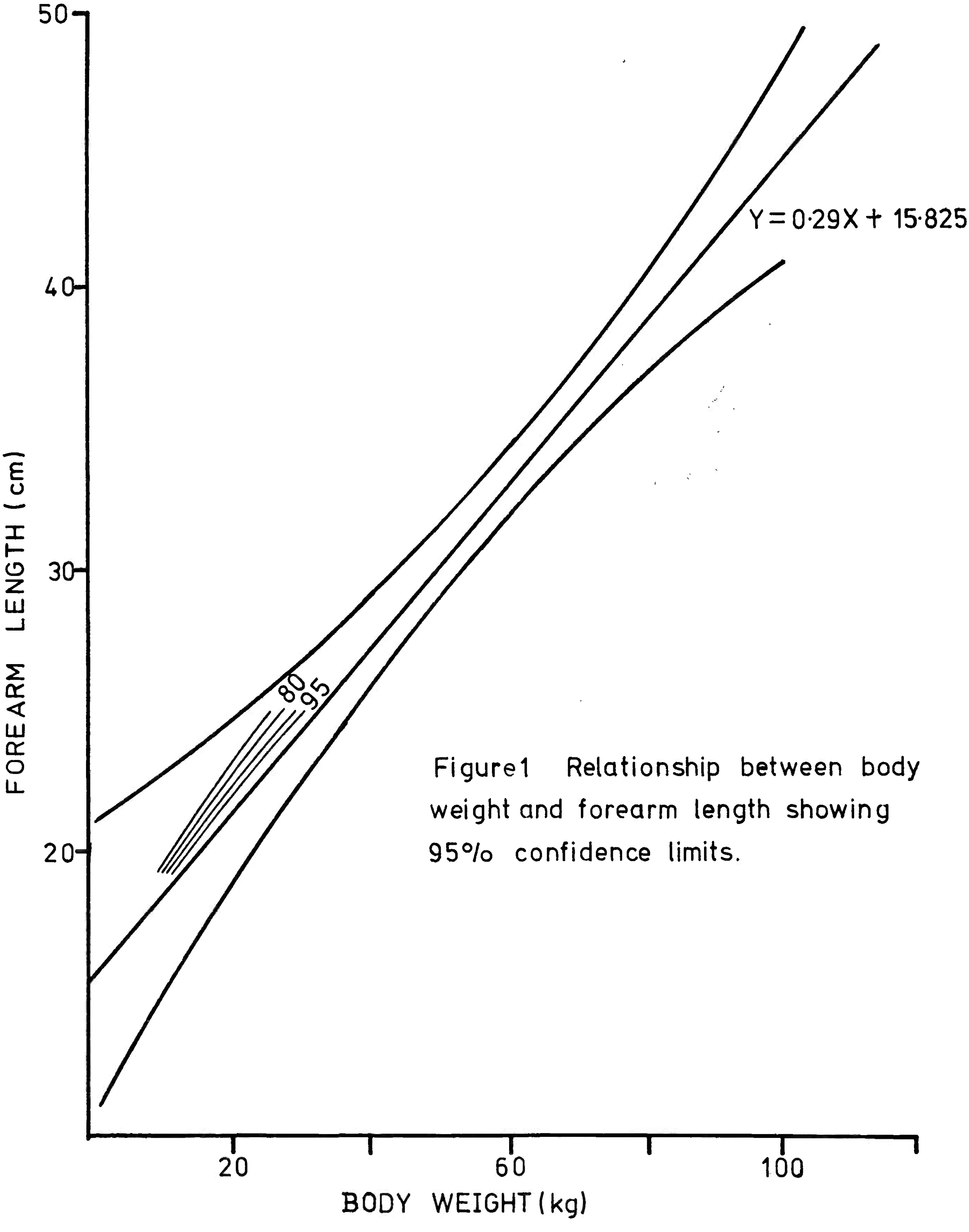

Figure1 Relationship between body weight and forearm length showing 95% confidence limits.

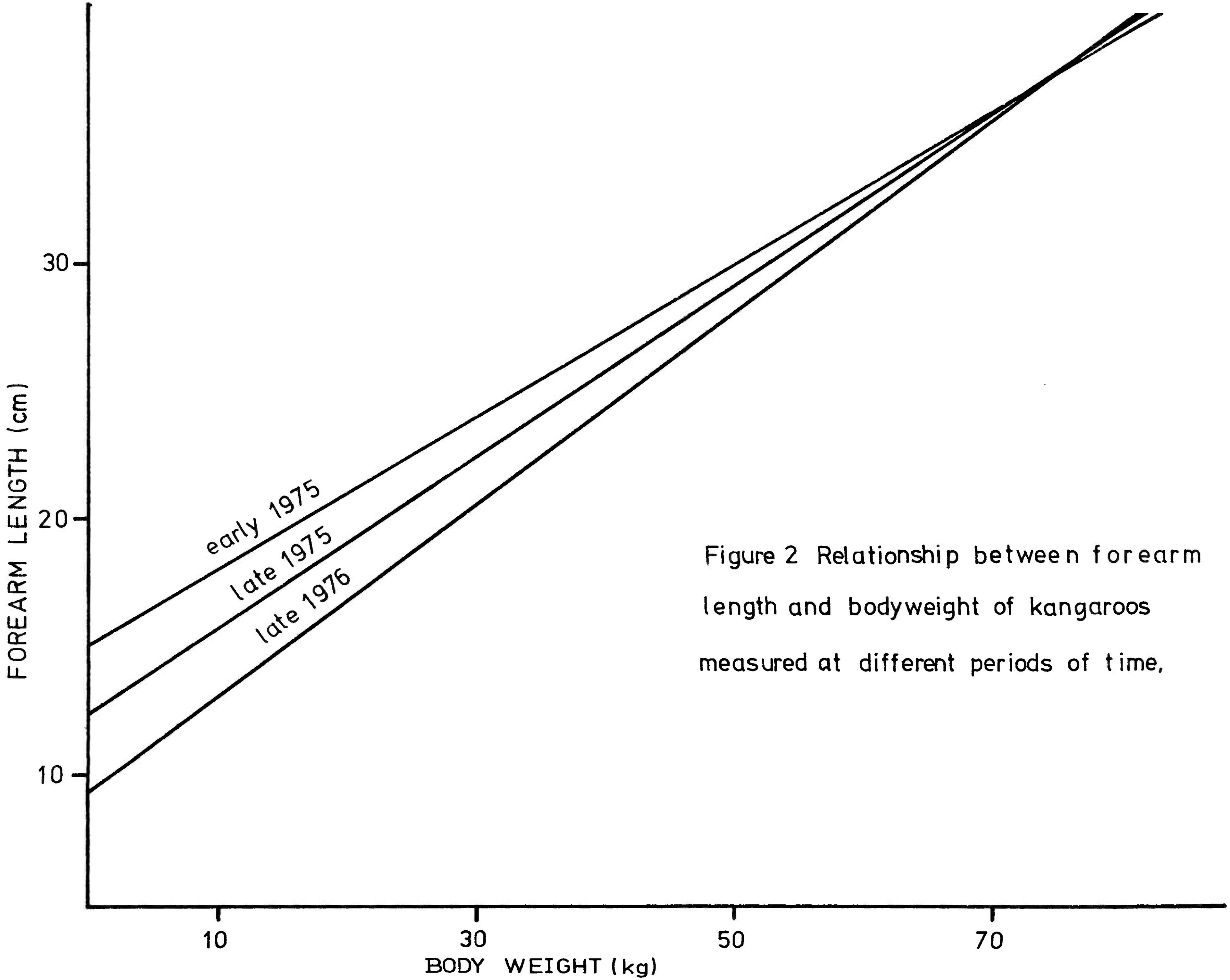

Figure 2 Relationship between forearm length and bodyweight of kangaroos measured at different periods of time,

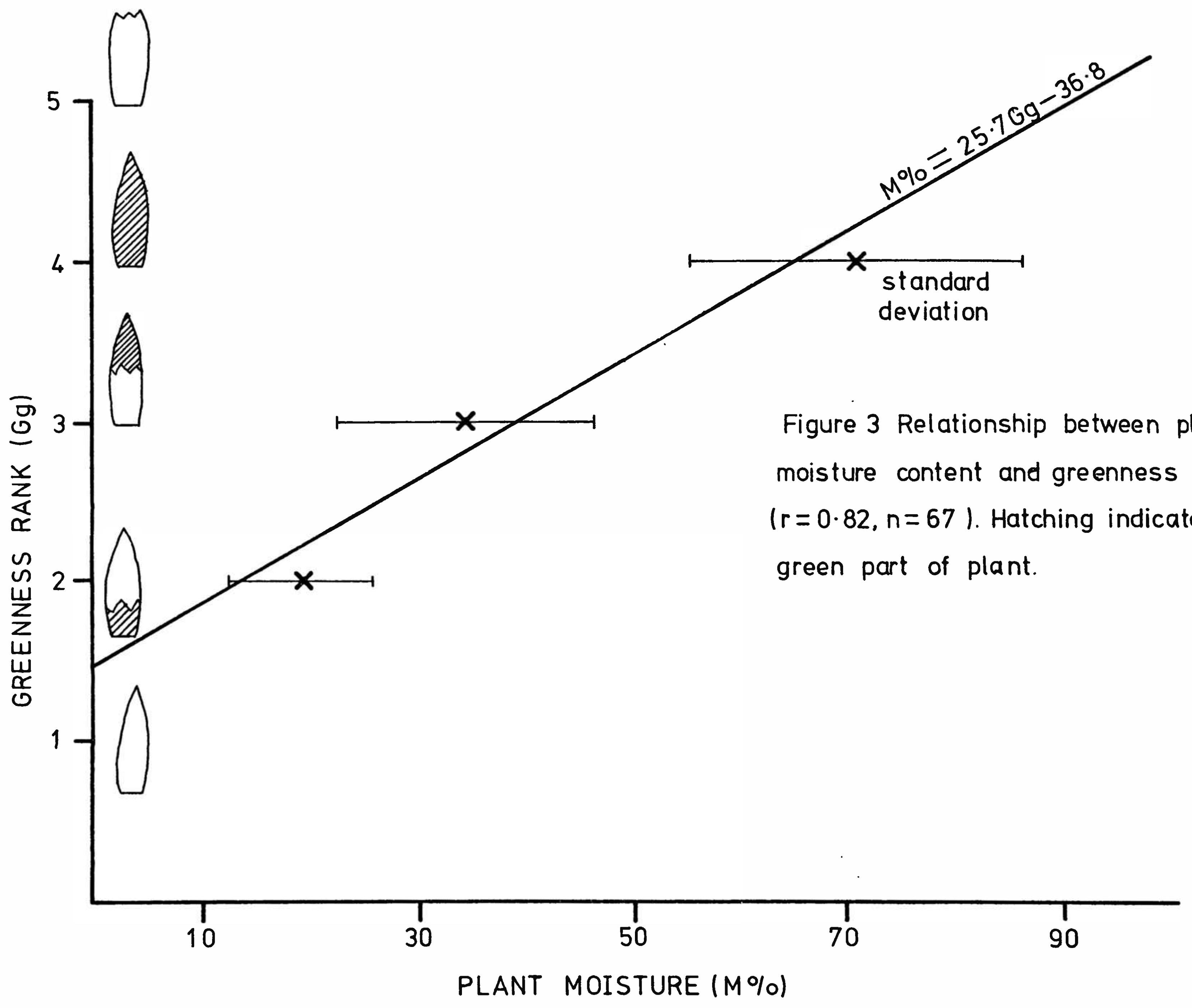

Figure 3 Relationship between plant moisture content and greenness ($r = 0·82$, $n = 67$). Hatching indicates green part of plant.

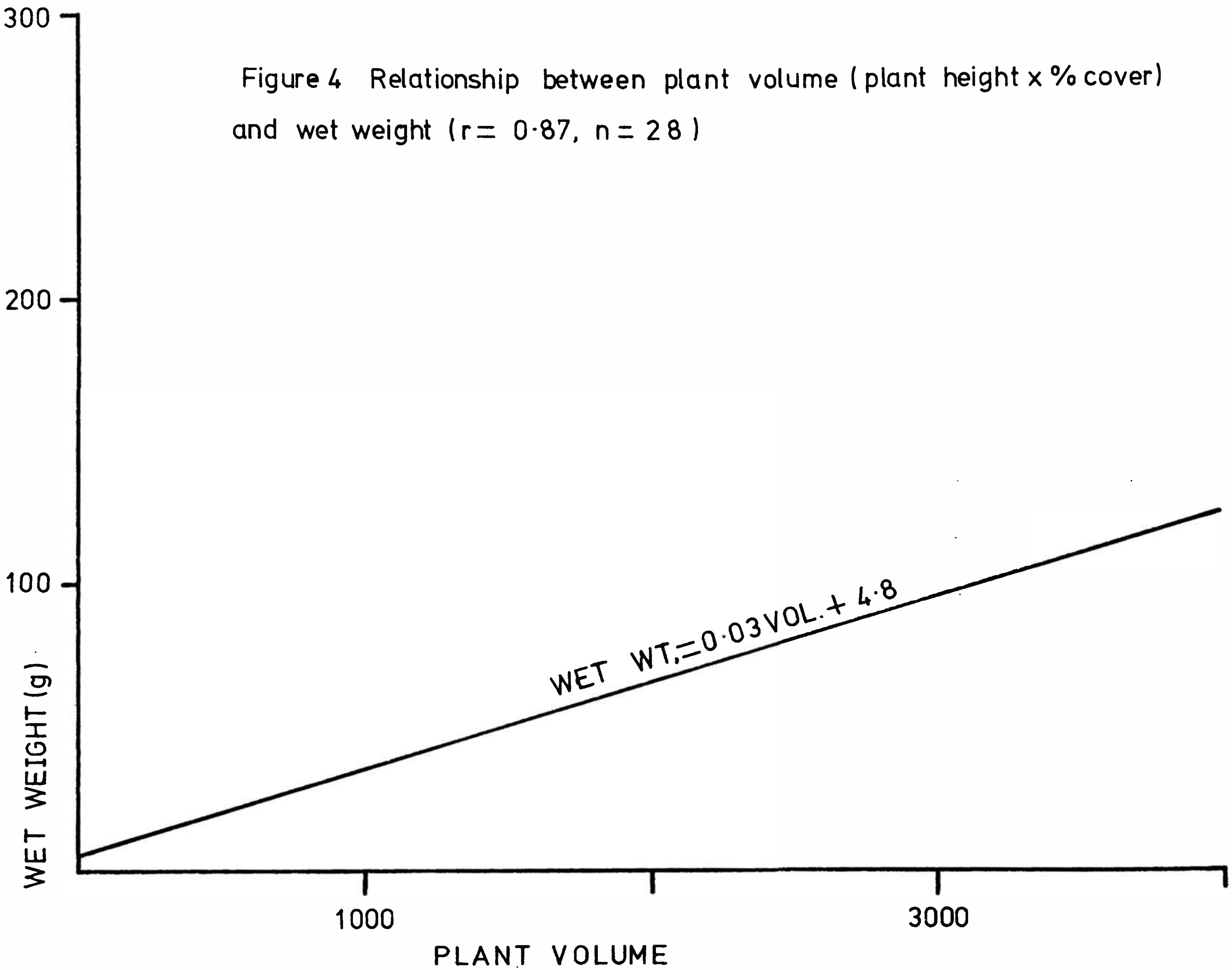

Figure 4 Relationship between plant volume (plant height x % cover) and wet weight (r = 0·87, n = 28)

BASAL AREA, DRY WEIGHT AND SIZE DISTRIBUTION OF INDIVIDUAL PLANTS OF SOME RANGELAND GRASSES.

by

J. A. Taylor[1] and R. D. B. Whalley[2]

A number of different criteria have been used to determine the response of rangeland to management and as an index of range condition (Parker, 1954). The most common methods involve estimates of the weight of herbage per unit area (Brown,1954) and/or species composition by weight (Pechanec and Pickford, 1937), or by basal area/cover (Roberts etal, 1976). The dry matter produced by individual plants of certain grasses in the rangelands of the Northern Tablelands of New South Wales has also been observed to respond to management and may be a useful criterion for such studies. However, most of the available techniques for estimating weight use 'quadrats' of various shapes and sizes and emphasize production per unit area. Such data often mask much information on the response of individual species to manipulation and on the process of changes in species composition. Furthermore, changes in the dry matter production per plant of key species (Sampson, 1952) may be a sensitive indicator of changes in range condition.

Work with individual plants has been hampered by the lack of effective means of standardizing plant weights for comparative purposes. Measurement of the basal area of individual plants would appear appropriate in this respect. However, measurement techniques such as Pearse (1935) and Vose (1956) suffer from the limitation that they assume that plant bases are regular in outline and that all within the outline of a plant base so defined is actually basal area. In reality, the measure consists of the cross-sectional area of both live and dead stems, as well as the area of airspace at the plane of harvest. The relative proportion of live stems, dead stems and airspace can vary tremendously from plant to plant and from species to species. Therefore, any device for estimating the cross-sectional area of only live stems must have an integrative capability as well as some precision in estimation. Observation of clipped plant bases through a transparent grid overlay appeared to fulfill these requirements.

This paper reports on laboratory and field studies on the measurement of basal area of individual grass plants, its relationship to the dry weight of green leaves of these plants and some possible applications of these measures to range condition and trend assessment.

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LABORATORY STUDIES

The laboratory work was designed to validate procedures for the use of transparent grid overlays. In these studies, thirty artificial plant bases of different sizes, four grid overlays of different dimensions and two methods of estimating area were examined.

Materials and Methods:

a) Grid Overlay Construction:

Transparent grid overlays of dimensions 10, 5, 3, and 2 mm were made by each of two processes:

1) etching fine lines on a sheet of two millimetre thick perspex; black or blue chinagraph pencil being used to enhance the visibility of the lines. A rigid durable grid resulted which was liable to fog up in the field in humid conditions.

2) photocopying graph paper onto acetate transparency sheets. A rapidly made, low cost and flexible grid. However, the photocopying process reduces the grid dimensions, particularly at the edges of a large transparency.

For this reason, only the perspex grids were used in the validation study.

b) Artificial Plant Bases:

Artificial plant bases were made by clustering, but not overlapping, adhesive black paper discs of 3.5, 2.0 and 1.0 mm diameter on paper to create ten 'bases' with each size of disc, each with a different basal area. The thirty clusters were intended to represent transverse sections of clipped grass plants of different species (using discs of different diameter) and of different basal areas (using different numbers of a particular size of disc). Field observations suggested the disc sizes employed and the range in basal area used for the validation procedures.

c) Area Estimates:

Two estimation methods were employed:

1) a count of the total number of grid cells estimated to be filled by the area of black paper discs, integrating part filled cells by eye;

2) a count of only those grid cells for which the paper discs occuppied more than half the area of a cell.

These estimates are henceforth referred to as filled-cell and half-cell methods respectively.

The two estimates of disc area were then compared with the actual area of discs for each artificial plant base. Regressions and correlation coefficients were calculated for each size of disc and grid and for each estimation method.

Results and Discussion:

The half cell method tended to underestimate area and appeared limited in field applications to species with large stems (Table 1). For these reasons it was abandoned.

In general, as disc size decreased, so the filled cell method tended to overestimate disc area, irrespective of grid size, as shown by the increase in slope (Table 1). Yet the relationship between estimated and actual area remained close irrespective of disc size. This suggests that for species with quite small stems (approximately 1.0 mm diameter) it is advisable to use a small grid. In other cases, larger grids can be selected depending on the basal area of the plants to be measured rather than the stem diameter.

TABLE 1

Results of a test of two methods of estimating 'basal' area using 10.0, 5.0, 3.0 and 2.0 mm perspex grids on thirty artificial plant bases constructed from clusters of black paper discs of 3.5, 2.0 and 1.0 mm diameter

Disc Diameter (mm)	Grid Size (mm)	Estimation Method[1]	Relationship between Est (estimated) and Act (actual) Area	Correlation Coefficient 'r'
3.5	10	a	Est = 0.0238 + 1.0049 Act	0.999
3.5	5	a	Est = - 0.1017 + 1.0484 Act	0.998
3.5	3	a	Est = - 0.0359 + 0.8756 Act	0.999
3.5	2	a	Est = - 0.1071 + 0.9336 Act	0.996
2.0	10	a	Est = 0.0497 + 1.0103 Act	0.971
2.0	5	a	Est = 0.0197 + 1.0417 Act	0.964
2.0	3	a	Est = 0.0493 + 0.9705 Act	0.939
2.0	2	a	Est = - 0.0522 + 1.4267 Act	0.966
1.0	10	a	Est = 0.0306 + 1.2678 Act	0.777
1.0	5	a	Est = 0.0023 + 1.4779 Act	0.940
1.0	3	a	Est = - 0.0076 + 1.4399 Act	0.966
1.0	2	a	Est = 0.0018 + 1.2466 Act	0.993
3.5	10	b	Est = 0.2377 + 0.5959 Act	0.829
3.5	5	b	Est = - 0.3320 + 1.0631 Act	0.963
3.5	3	b	Est = 0.2459 + 0.5374 Act	0.900
3.5	2	b	Est = - 0.1225 + 0.5640 Act	0.938
2.0	10	b	Est = 0.1076 + 1.5532 Act	0.044
2.0	5	b	Est = - 0.1309 + 0.7284 Act	0.597
2.0	3	b	Est = - 0.0039 + 0.2396 Act	0.361
2.0	2	b	Est = 0.0191 + 0.6083 Act	0.875
1.0		b	Est = [2]	

[1] a = filled cell method
b = half cell method

[2] By definition and with the grid sizes listed, this method must fail.

FIELD STUDIES

Initially, field studies were intended to develop a method for the estimation of basal area and the dry matter yield per unit basal area of different species. The procedure below was adopted after much trial and error and use in the field by undergraduate students. The final procedure was used to establish the relationship between basal area (as measured with a transparent grid overlay) and the dry weight of green leaf blades of plants of different grass species growing at different sites at more or less the same point in time.

Methods:

Twenty plants, representing the range in plant size of a species at a site, were clipped as low to the ground as possible. Grid overlays were placed, etched side down, on either the clipped plant base or on an inverted hand-held clump of the tops, trimmed square with shears. Estimates of basal area were made with a 5 mm grid to the nearest quarter of a filled grid cell and expressed as a count of filled cells. Tops were bagged, labelled with the basal area estimate and transported to the laboratory in sealed plastic bags. The material was then sorted and dead matter, flowering culms and sheathing leaf bases discarded. Only those blades green for greater than half their length were dried at 85°C for twenty-four hours, then weighed. This is the value described as leaf weight.

One hundred plants of seven selected species were sampled at random at different sites for the frequency distribution of different basal areas.

Species examined included *Aristida* spp, *Bothriochloa macra* (Steud.) S.T. Blake, *Chloris truncata* R.Br., *Cymbopogon refractus* (R.Br.) A.Camus, *Danthonia* spp, *Eleusine tristachya* (Lam.) Lam., *Eragrostis* spp, *Eulalia fulva* (R.Br.) O. Kuntze, *Panicum effusum* (R.Br.), *Poa sieberana* Spreng var. *sieberana*, *Sorghum leiocladum* (Hack.) C.E.Hubbard, *Sporobolus elongatus* R.Br., *Stipa variabilis sensa lato* and *Themeda australis* (R.Br.) Stapf..

Results and Discussion:

Leaf Weight / Basal Area Relationships:

Species with a tufted or tussocky habit consistently showed useful and significant (r 0.80), though different, straight line relationships between leaf weight and basal area (Fig. 1). Many of these species such as *C. refractus*, *S. leiocladum* and *T. australis* were probavly components of Tableland pristine communities and decrease under grazing (Norton, 1971). Figure 1 also indicates that these species are characterized by far more available forage per unit basal area than many of the increasers/invaders that are now present day dominants eg. *B. macra*. Species whose growth habit changes in response to management, such as *B. macra*, *C. truncata*, *E. tristachya* and *P. effusum*,were generally inconsistent in both the nature and significance of the leaf weight/ basal area relationship. The relationship is also poor with species whose leaves are cauline rather than basal; eg. *A. ramosa*. This suggests that changes in leaf weight per unit basal area of these sorts of species is not particularly sensitive to management and that such species could prove poor key species.

However, from Figure 1 a change in the slope of the straight line describing some of the more useful weight/basal area relationships appears to be a function of rate of fertilizer, grazing pressure or range condition. It could also be a function of time and provide a measure of growth and defoliation of a species. As regards fertilizer and grazing it remains for the value of this observation to be further examined. In terms of range condition, the weight/basal area relationship of plants of Danthonia with a fairly wide ecological amplitude (Scott, pers. comm.), were recorded at sites subjectively assessed by the authors as being in poor, fair, good and excellent condition (Fig. 2). An apparently strong relationship exists between leaf weight per unit basal area of this species and condition. However, any further inference is limited by the subjectivity of our assessment of condition. The trend of the results can be expressed in another way (Fig. 3), which suggests that this species is an increaser (Dyksterhuis, 1958) that may in fact reflect the trend in condition of the range. Quite possibly a whole family of such curves exists for other tufted species that are common to sites in different condition. These species would appear to be ideal key species.

Size Distribution of Grass Plants:

Although the plants in Figure 2 were not selected at random, the data suggested that as well as differences in weight per unit basal area, the frequency distribution of basal area itself seemed to reflect range condition. To investigate this further, 100 randomly selected plants of Themeda australis were clipped at each of three different sites and the basal area of each plant measured with a 5 mm transparent grid overlay. Figure 4 shows differences in size distribution of the T. australis populations associated with differences in grazing pressure and presumably range condition.

If the size-age relationships for each species and site were known, it might be possible to analyse the population structures in terms of what changes are occurring and what changes are likely in response to a particular manipulation. Rabotonov (1969) has distinguished invasion, normal and regressive types of coenopopulations according to their 'age spectra' and Kershaw (1973) has indicated that ...." in general terms there exists a direct relationship between age, performance and competitive ability, potentially, for most if not all perennial plants". However, quantitative in situ assessment of the age of individual grass plants remains a problem (Kershaw, 1962). The major difficulty seems to be that the rate of increase of basal area of any one species is probably dependent on seasonal conditions as well as soil fertility, grazing pressure and other condition related factors.

However, the frequency distribution of the basal area (age(?)) of 100 plants of six species growing at 3 different sites were examined as a further assessment of the possibilities of the concept. Three quite different frequency distributions are evident (Fig. 5). Assuming age to be proportional to basal area, the nature of the frequency distributions of S. leiocladum and C. refractus suggest a stable population of long lived individuals; A. ramosa and E. brownii, a young and invading population, and B. macra and S. elongatus a population of short-lived individuals with a rapid turnover. If these suggestions are true, a change in the frequency distribution of the basal area of a key species would appear to indicate a change in trend.

CONCLUSIONS

A simple measure of the basal area of individual plants of a number of grasses has, through various applications generated a host of new hypotheses on the selection of key species and assessment of condition and trend in perennial grass pastures. A great deal of supplementary work is necessary to assess the true value of the notions presented in this paper and for those interested to pursue the many avenues, guidelines for field use of the transparent grid technique for measuring basal area, are presented:

1. Although twenty plants of a species were examined in the study reported here, as few as five plants have been found to provide significant linear relationships between leaf weight and basal area of some species in certain cases.
2. With this technique it is advisable to check and review estimates of basal area against black disc standards both before and during a program of basal area measurement.
3. The individual plant referred to can consist of either a discrete tuft of grass or a number of vegetative stems of a large tuft. Either way, the technique appears to work well.
4. The inclusion of the cross-sectional area of flowering culms in the basal area estimate invariably weakened the left weight/basal area relationship and it was difficult to distinguish, and so visually separate, what was a flowering culm from a vegetative stem in a clipped plant base. For this reason, the hand held estimate is to be preferred. Alternatively, coupling species in the vegetative phase would give better correlations.

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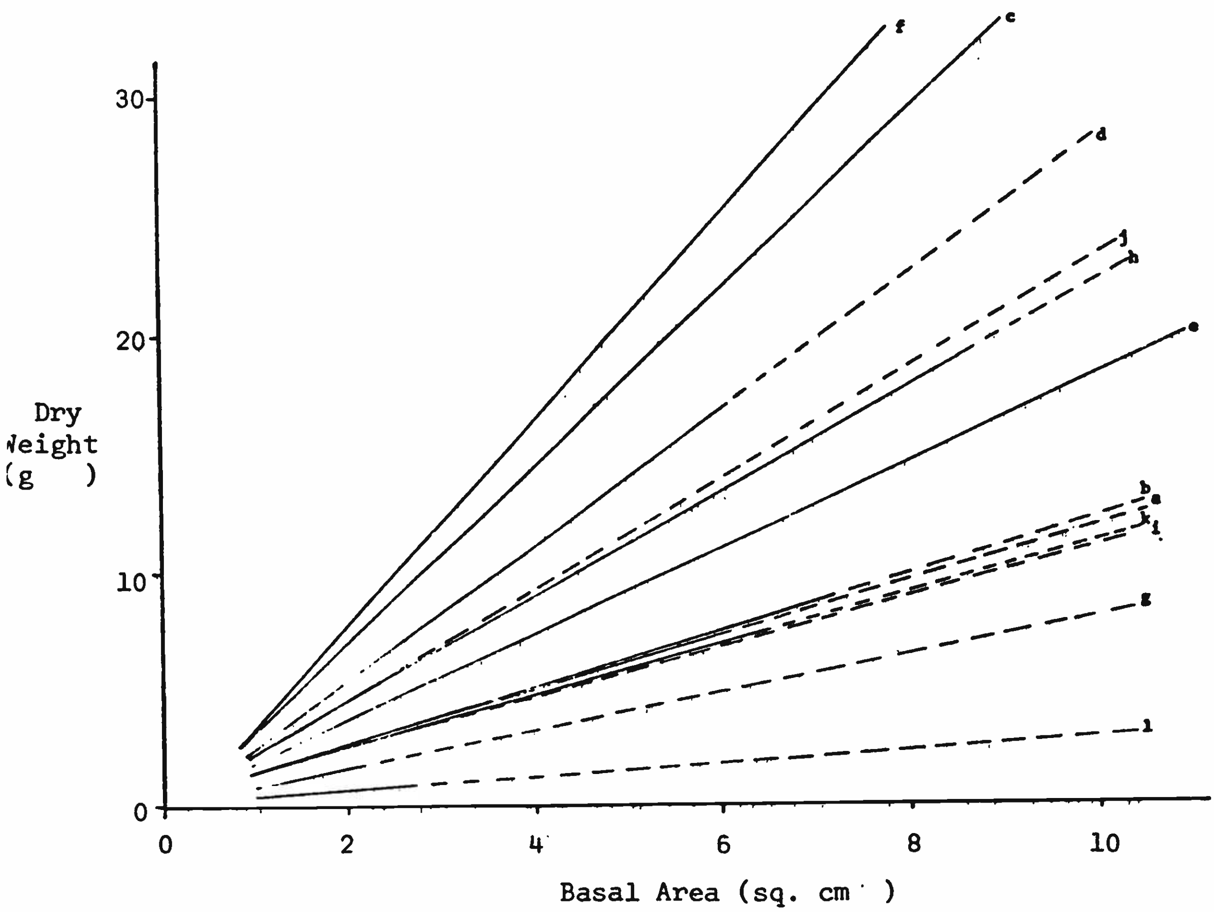

FIGURE 1: Relationships between leaf weight and basal area of individual plants of different grasses growing at different sites:

a) T. australis, traprock, continuous light grazing (r = 0.966)
b) " , " , grazing excluded for 2.5 years (r = 0.947)
c) " , " , road verge, occasional light grazing (r = 0.944)
d) " , " , " " , " " " (r = 0.973)
e) S. leiocladum, " , continuous light grazing (r = 0.960)
f) " , " , road verge, occasional light grazing (r = 0.959)
g) P. effusum, " , grazing excluded for 2.5 years (r = 0.812)
h) C. refractus, " , road verge, occasional light grazing (r = 0.947)
i) S. elongatus, " , grazing excluded for 2.5 years (r = 0.904)
j) " , granite, cultivated, 70 kg Starter 18^R/ha (r = 0.990)
k) B. macra, traprock, grazing excluded for 2.5 years (r = 0.865)
l) " , " , heavily grazed (r = 0.375)

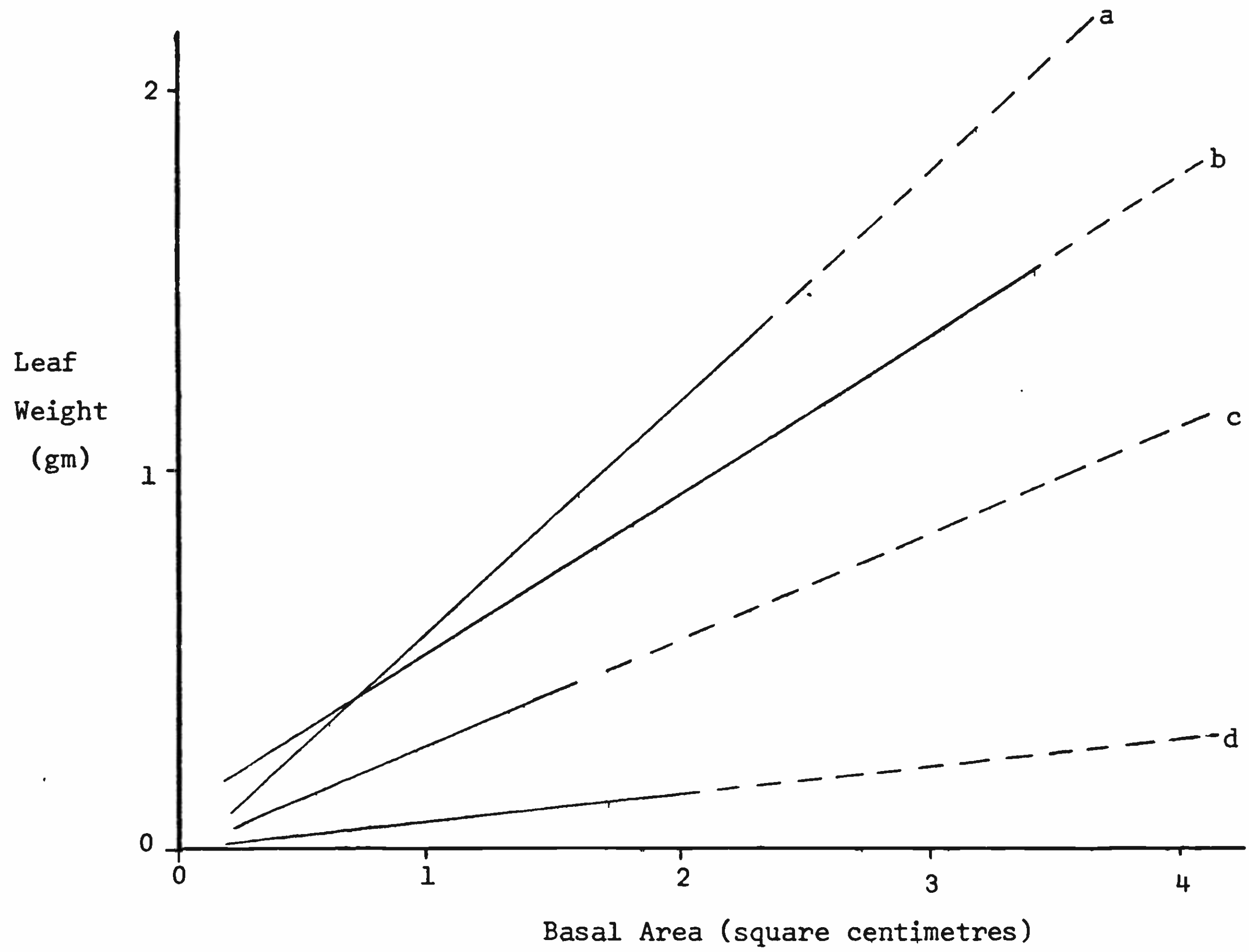

FIGURE 2: Relationship between dry-weight of leaves and basal area of Danthonia __________ at sites subjectively assessed to be in different condition:
a) 'good' condition, b) 'excellent' condition, c) 'fair' condition, d) 'poor' condition.

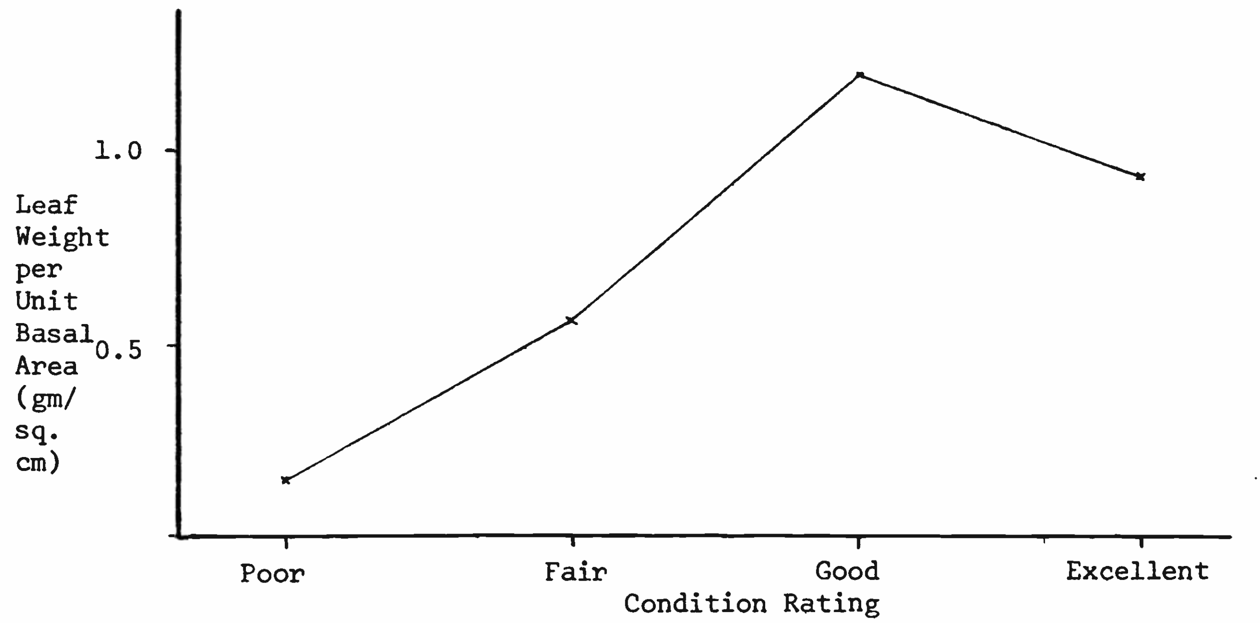

FIGURE 3: Suggested relationships between a subjective assessment of condition and leaf weight per unit basal area of Danthonia __________.

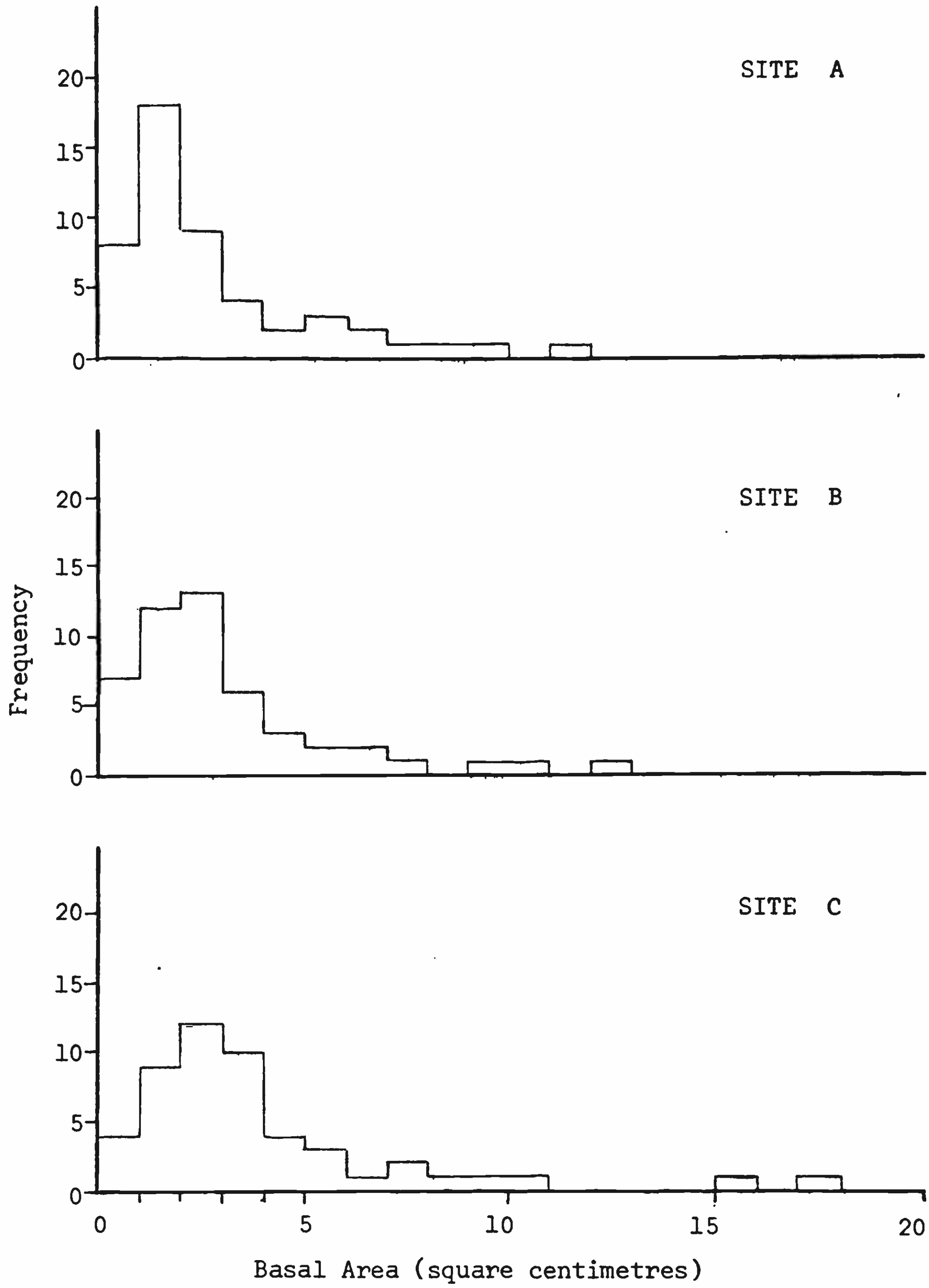

Figure 4: Frequency distribution of the basal area of Themeda australis plants recorded at three different sites:

a) continuous light grazing, 'fair' condition

b) adjacent to (a), but grazing excluded for the last 2.5 years; 'good' condition

c) road verge, occasional light grazing, 'excellent' condition

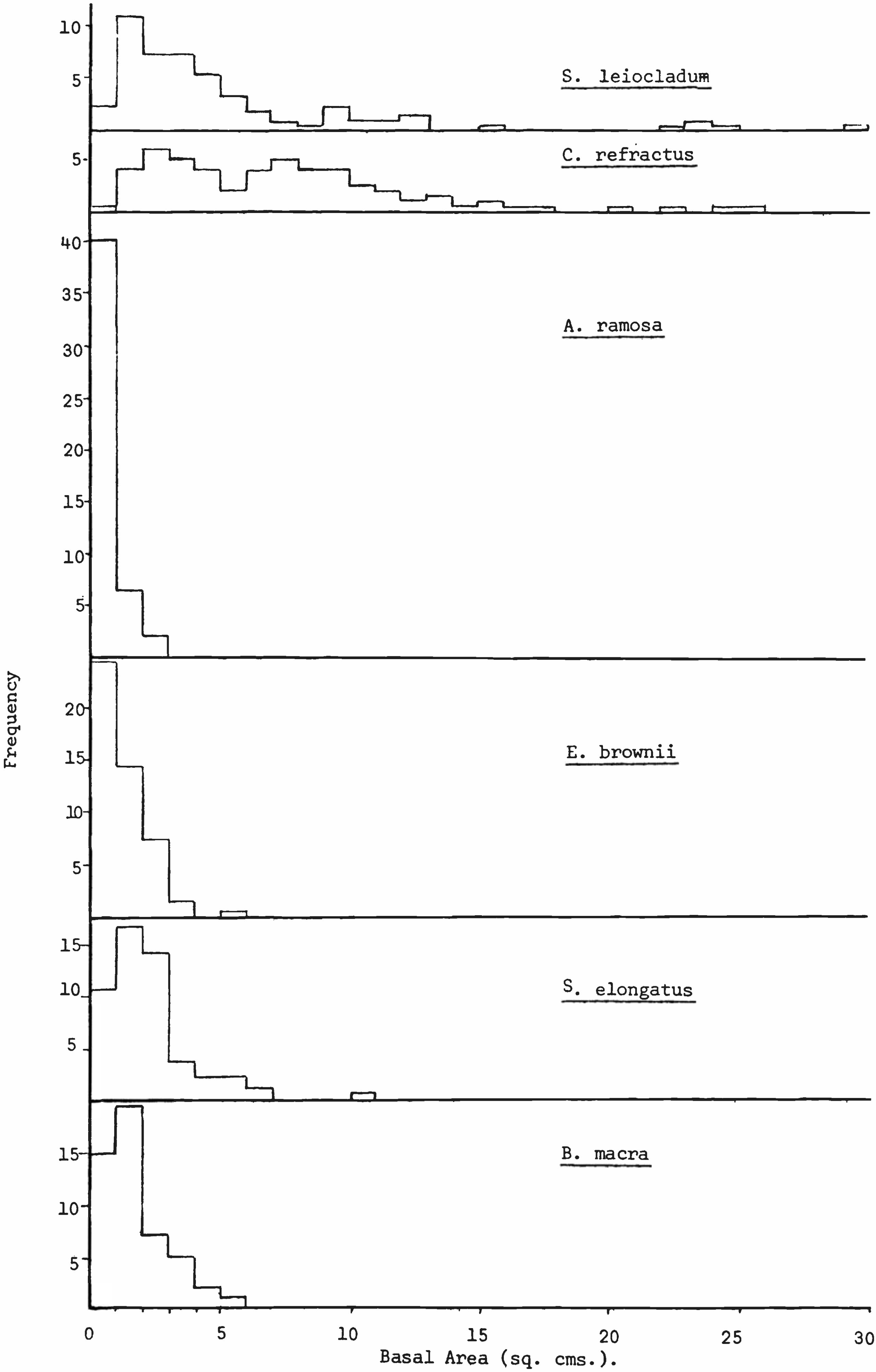

FIGURE 5: Frequency distribution of the basal area of different species.

STUDIES AT COBAR EXPERIMENTAL AREA, COBAR, N.S.W.

by G.M. Cunningham, *

P.J. Walker and +

D.R. Green. +

INTRODUCTION

The initial study program relating to reclamation of the hard eroded ridges of the Cobar Pediplain, has recently been completed at Cobar Experimental Area.

The studies involved treatment of the area by mechanical methods and subsequent measurements of their effects.

SITE DESCRIPTION

When investigations commenced at Cobar, the site was a bare, eroded ridge supporting very little ground cover. The 81 hectare area had been heavily grazed for many years and most of the larger trees had been removed for mining and other purposes.

The site consists of a main ridge about 10 metres above the centres of the drainage flats which surround it on three sides. Slopes vary from about level on the ridge tops to five percent on the steeper areas. The site is approximately 250 to 270 metres above sea level.

The median annual rainfall at Cobar Experimental Area is 325 mm. Temperatures are hot in summer and cold in winter (34.6°C mean maximum for January; 4.1°C mean minimum for July). Limited evaporation measurements indicate annual loses of 2350 to 3005 mm from a free water surface.

The major tree species include bimble box *(Eucalyptus populnea)*, red box *(Eucalyptus intertexta)*, white cypress pine *(Callitris columellaris)* and mulga *(Acacia aneura)*. A wide range of shrubs is also evident.

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Soil descriptions were carried out as part of a larger scale soil survey, and involved examination of a typical ridge catena and of selected sites on and adjacent to the Experimental Area.

On the ridge crests and upper slopes occur shallow stony medium - textured lithosols (Northcote Um 1.43). These are acid, reddish brown in colour and no more than 30 cm deep, and are, in fact, the B horizons of the original soils, from which the surface 10 cm or so of coarser textured materials has been eroded by water sheeting. The present soil surface is vary hard, and has a very low infiltration capacity.

The soils of the mid-slopes and lower slopes become gradually deeper and less stony than the ridge soils, and have uniform medium - textured profiles (Um 1.43) on the mid-slopes with gradational red earth profiles (Gn 2.13, 2.12) on the lower slopes. These lower soils are underlain by a "Hardpan" - an apparently fluviatile layer which is impenetrable to soil sampling equipment and most plant roots. The greatest effective plant rooting depth measured at the site is 65 cm .

All soils contain low levels of available phosphorus, total nitrogen and organic matter, and relatively high levels of exchangeable sodium.

Small areas of residual topsoil and water or wind deposited coarser material (sandy loam, sand) occur in rill-lines and near the ridge crests. These soils have a much higher infiltration capacity, because of the coarse surface layer, and it is only in these situations that vegetation growth occurs in all but very wet years.

MECHANICAL TREATMENTS

Three different structural treatments were used at the site in an endeavour to stimulate revegetation. These were:-

Ripping - belts of three contour rip lines with one metre between the individual rip lines forming a belt 2 metres wide. These were separated from adjacent belts by an untreated space of 6 to 10 metres width. Similar belts of rips were later constructed midway between the original belts.

Close Furrows - contour furrows from 1 to 1.5 metres apart down the slope. These furrows were approximately 30 cm wide and were interrupted every 50 to 60 metres, by an unfurrowed gap one of two metres wide.

Wide Furrows - contour furrows from 3 to 5 metres apart down the slope and constructed as above.

An untreated area served as a control. Superimposed on these treatments were grazing and enclosure. Most furrowing and ripping on the Experimental Area has been carried out on the upper and mid-slopes and the ridge crests.

VEGETATION STUDIES

a) Ground Flora

i) Period 1963 - 1968

Observations over the five years immediately following treatment indicated that structural treatments as well as exclosure were essential to the revegetation of this eroded site. Close furrows were the most effective structural treatments, followed by wide furrows and ripped belts. Exclosure alone showed little response.

There were few significant differences in vegetation establishment following winter and summer structural treatment, but experience suggests that where possible, treatment should be carried out in cooler months to aid plant establishment.

Both exclosure and soil disturbance were essential to the establishment of perennial forbs. These species were conspicuously absent under grazing but present in wide array after five years of exclosure. The harsher perennial grasses, however, appeared less susceptible to grazing and were the predominant species on heavily and continuously grazed areas.

Even with complete exclosure, perennial cover decreased during severe droughts, illustrating the dynamic nature of ground cover and showing that major fluctuations in perennial cover occurred independently of man's influence.

In this period, cover was largely associated with mechanically disturbed sites, with some spread onto interfurrows and interbelt (rips) areas. Despite the influence of mechanical treatment, the greatest amount of ground cover established during this initial five year period was a 40% cover.

(ii) Period 1972 -1975

The prime difference between the (1963-68) and (1972-75) observation periods was that during the latter period some sections of the site were grazed to allow observations to be made on the effects of controlled grazing as opposed to continuous grazing on vegetative cover production.

One major factor demonstrated during this period was the lag in cover production after a dry spell. The minor drought of winter - spring 1972 and summer 1973, was followed by good rains from autumn 1973 onwards. However, mean total pasture cover did not rise significantly above the drought levels until autumn 1974. This result indicates the need to restrict stocking for a period after drought breaks, to allow plants to germinate and establish resistance to grazing.

The trial again indicated during the later observation period, that two inputs were required to reclaim eroded ridge soils in the Cobar area; structural treatment (surface disturbance) and stocking control (exclosure and spelling periods).

The type of structural treatment is important. In the trial, widely spaced furrows produced highly significantly more perennial grass cover than the close furrows regardless of stocking pressure. Under controlled grazing, close furrows produced more total pasture, while under continuous "Heavy" grazing the wide furrows produced more total pasture. The wide furrowed/ control grazed area produced the best balanced pasture, with annuals, perennial forbs and perennial grasses contributing approximately equally to the total pasture.

The selection of furrow spacings required will depend on costs, pasture type requirements and stocking management.

(iii) Change in Species Array

When Cobar site was exclosed, only twenty separate ground flora species (12 grasses and 8 forbs) were recognised. However, by June, 1974, eleven years later, 119 species (32 grasses and 87 forbs) were evident on the area

Although detailed information is not available on the original pastures, perusal of available literature indicates that the basic elements of the original pastures are still present, although relative abundance relationships may have changed.

(b) Tree and Shrub Growth and Regeneration

Heights of trees and woody shrubs were measured during the period September, 1964 to September 1974, in adjacent furrowed grazed (1 sheep per 2.5 hectares) and ungrazed areas, to determine the effects of grazing, season and rainfall on growth rates. The main species measured were mulga *(Acacia aneura)*, white cypress pine *(Callitris columellaris)*, and turpentine *(Eremophila sturtii)*.

It was shown that the growth rates of ungrazed mulga and pine trees were significantly greater than those of grazed plants, but for turpentine no significant difference occurred. Mean annual height increments of ungrazed mulga, pine and turpentine were 0.24, 0.20, 0.09 metres respectively, whilst for grazed plants mean annual increments were 0.14, 0.12 and 0.08

metres respectively,

From the limited seasonal data available, it appeared that growth was more rapid in summer than in winter. For all but ungrazed turpentine, height increments of grazed and ungrazed plants were significantly correlated with rainfall. Growth rates, especially of mulga, increased sharply in the wet September, 1973 to March, 1974 period, but were very low during the initial part of the observation period and during the dry year, 1972.

Deaths of plants during the trial were minimal (2 out of 68 mulgas, 1 out of 55 pines and 5 out of 91 turpentines).. Almost all deaths occurred before 1972.

Studies of shrub regeneration were also carried out. However, no significant difference between regeneration on grazed and ungrazed plots occurred, nor could regeneration be statistically related to current rainfall. A nil or only very slight increase in total plant numbers occurred up to 1969, after which a gradual increase occurred on all plots, and with a marked increase on one plot after September, 1974.

Final plant numbers were:

grazed mulga and turpentine 1.7 times the initial number

grazed pine 3.5 times the original number

ungrazed mulga 2.2 times the original number

ungrazed pine 5.5 times the original number

ungrazed turpentine 14 times the original number.

(c) Effects of Grazing on Vegetation

A small grazing trial carried out at the experimental site between 1968 and 1973 produced several significant results.

The stocking rate prior to furrowing was assessed at one sheep to ten to twelve hectares. During the trial the furrowed areas were stocked on average at one sheep to 2.3 hectares, and on two of the paddocks used, the stocking rate over the five years of the trial was one sheep to less than 1.5 hectares. These rates were applied without any medium to long term pasture degradation.

An examination of the effect of length of time between contour furrowing and grazing (i.e. the spelling period) produced interesting results. Areas spelled for two and five years produced similar average pasture cover during the trial, whereas areas spelled for less than eighteen months produced much lower average cover. This indicates that newly treated areas need to be spelled for at least two years and possibly longer, depending on seasonal conditions.

During the trial, one paddock was grazed predominantly during the summer period, with another during the winter period. The summer grazed paddock produced a predominance of winter annual species whereas the winter grazed pasture had a dominance of perennial species, mostly summer growing. Although this result is confounded with differences in furrow spacing, there was an indication that species manipulation may be possible through grazing management.

SOIL STUDIES

(a) Rainfall and Runoff Studies

Runoff from two small plots 3.22 metres long by 1.22 metres wide (designed to simulate the interfurrow distance of wide furrows) was measured between May, 1968 and February, 1973. Rainfall amount and intensity were measured by a pluviograph.

One plot was located on a smooth, crusted soil surface and one was on a gravel-covered surface - the two soil surface conditions commonly occurring on the Experimental Area.

Wherever possible runoff from single rain fall events was measured, with 140 events being recorded during the trial period.

Recorded runoff ranged from 0 to 81 per cent of incident rainfall on the gravelly plot, and from 0 to 87 per cent on the smooth-surfaced plot. Rainfall amount accounted for 84 to 89 per cent of variation in actual runoff, and intensity accounted for a further 5 per cent of the variation. Neither antecedent rainfall nor season significantly affected runoff.

Threshold rainfall amounts for runoff to occur were calculated from rainfall/runoff regressions for each plot. These were 5.1mm for the gravelly plot and 4.8mm for the smooth plot. In practice, however, 21 positive runoff events occurred at lesser amounts of rain fall on the smooth-surfaced plot. The gravelly surface sheds 34 per cent of its annual rainfall as runoff, whilst the smooth surface sheds 45 per cent of its rainfall. Falls of less than 5mm of rain comprise from 4 to 50 per cent of its annual rainfall in this district, and runoff occurs about 19 times each year on average.

On contour-furrowed ridges irrigation of the furrows occurs after rains of 5mm or more. Thus an annual basis furrows 3 metres apart effectively receive about four times the incident rainfall.

(b) Soil Moisture Studies

Gravimetric soil moisture measurements were initiated soon after studies commenced at the Cobar site to ascertain the degree of the influence of the mechanical treatments on soil moisture levels.

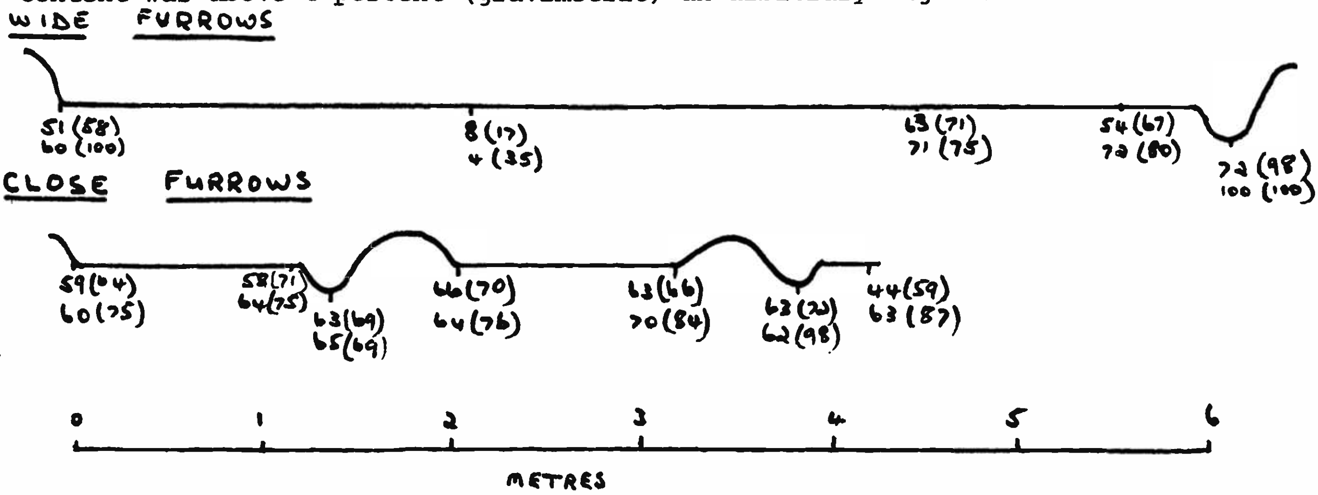
Sampling was carried out at the soil surface (0 - 1 cm depth) and at 10cm depth. Results revealed that the zone of influence for both riplines and furrows was limited to the immediate vicinity of the structure. The extent of this influence varied with depth, particularly on the ripped areas.

Perhaps the major outcome of the study was the revelation that soil moisture levels on control areas and those between the furrows and ripped belts rarely exceeded accepted field capacity levels. This explains why vegetation establishment on these areas was poor during the initial stages of the Cobar studies. It was only after the prolonged wet periods of the 1970's that vegetation establishment began in earnest.

This study also revealed greater soil moisture levels under the furrows than under the ripped areas, suggesting greater efficiency in runoff water trapping by the furrow line.

The soil moisture regime in transects across wide and close furrows was measured again with gypsum blocks in a more detailed study between October, 1974 and September, 1975. Blocks were placed at 5 cm and 10 cm depths between, adjacent to, and in furrows, and the drying cycles of the soil were measured. Wetting rate was estimated from pluviograph records and antecedent soil moisture.

The percentage of total time that the moisture content at each depth was above wilting point (taken as pF 4.2 for want of a better figure) is shown diagrammatically below. Figures in brackets indicate percentage time moisture content was above 4 percent (gravimetric) an arbitrary figure.



These figures show that furrows markedly affect the soil moisture regime at all positions in and adjacent to furrows, with the exception of the interfurrow space between wide furrows, where the moisture regime would be very similar to unfurrowed ridges. At this site a fall of 39 mm of rain was required to bring the soil moisture content at both depths above wilting point. This is not surprising since the site is characterised by the absence of vegetation except for a few Bassia diacantha plants after 13 years without stocking and 3 years of excellent rainfall. Mixed vegetation of varying quantities grows at all other sites.

(c) Soil Temperature Studies

Limited measurements of surface and 10cm depth soil temperatures were made over a four day period in May, 1965. Maximum temperatures as well as the diurnal fluctuations were recorded in furrow base and interfurrow sites under varying amounts of cover.

Increasing degrees of cover produced increasing reductions in maximum daily temperature as well as in the diurnal fluctuations. This effect was evident both at the surface and at 10cm depth.

The overall effect of this amelioration of the soil temperature regime by the primary coloniser cover in the furrows was to provide suitable germination sites for more useful pasture species. Grazing at this time removes this primary coloniser cover and results in a less favourable environment for establishment of more useful species. This provides a further case for exclosure in the years following treatment of bare areas in the Cobar district.

It is unfortunate that a parallel study was not conducted in summer to quantify summer maxima and diurnal fluctuations. However, the study illustrated the major temperature fluctuations experienced on bare sites in winter and showed that relatively high temperature maxima (30°C approx) can be experienced in winter.

CONCLUSION

Studies at Cobar Experimental Area have provided a much needed quantification of the soil environment of an eroded ridge site representative of large sections of the district. The information obtained has explained why, without soil disturbance, water trapping and grazing control little can be achieved in regenerating eroded areas in "non-wet" years.

The trials also illustrated the value of contour furrows as a revegetation tool and showed how soil disturbance combined with exclosure has greatly widened the array of ground flora species.

The limited grazing trial at the Cobar site has provided an encouraging indication that pasture species composition in the area may be manipulated by grazing at specific times.

THE USE OF RANGELAND INVENTORIES

E.J. Turner

Introduction

Land system mapping of the resources of the arid and semi-arid lands in Queensland is continuing. To date, some 31 million hectares of pastoral land have been mapped. The reports have either been printed or are soon to be printed. The need for these resource inventories has long been recognised. The basic biological data collected has been used by quite diverse organisations. Users at the State level include:

(a) Irrigation and Water Supply Commission in selecting potential irrigation areas.

(b) Valuer-General's Department - as an aid in assessing valuations in South West Queensland.

(c) National Parks and Wildlife - to identify those areas which should be set aside for public use. Research in U.S.A. indicates that the land system concept can be used to evaluate habitat suitability for wildlife. (Hawes and Hudson 1976).

(d) Co-ordinator General - bases its recommendations for regional development upon an appreciation of land systems.

The land system concept is also suitable for planning extension and research at the property level. The D.P.I. in Queensland used the land system approach for planning the development of new properties in the Brigalow Scheme (Turner 1975). All properties were mapped at the land unit level and development was planned after each land unit was assessed in terms of its potential and possible limitations. The various land units were then grouped into management classes which were really indicators of areas of different potential. These management classes established the priorities for property development.

The land system concept also lends itself to ecological research, in particular condition and trend (Dyksterhuis 1949). If trials are confined to one land unit in a particular land system, then variability between sites should be minimal. Ideally, reactions to land use on any one particular unit should be capable of extrapolation to the same unit in another locality. Research along these lines is presently being undertaken by Orr (personal communication) who is studying the effects of grazing pressure on *Astrebla* grasslands within one particular land system.

Condition assessments

Assessments of the status of major vegetation communities in WARLUS Part IV were made in winter 1974. Soil measurements were also done as they were considered necessary in any long term monitoring programme.

Methods

The wheel point method was used with a sample size of 3 x 300 points over a triangular course. This was considered sufficient to give an estimate of basal cover and botanical composition. Roberts (1972) reports that 500 wheel points is adequate for botanical composition but greater than 500 is necessary for basal cover. Soil samples were taken to establish surface variability and to investigate the variability in bulk density on the 0-10 cm layer. Nine sample points were used at each site and a soil sample taken every 100 wheel points.

Results

(a) Soils: The results for two major vegetation communities are summarised in Table 1. It is intended to publish the complete data later.

Table 1. Mean Values and Coefficients of Variation.

Acid and bicarbonate extractable P showed large coefficients of variation. The difference in nutrient levels of samples taken beneath the tree canopy and inter-canopy zone was very marked (Edye *et al.* 1964, christie 1975). Coefficients of variation were low for pH, total K and bulk density. Moderate coefficients of variation were recorded for total N, exchangeable and replaceable K. C.E.C. showed low coefficients of variation at the higher values and increased variation at the lower values. This has been attributed to the limitations of analysis (Ahern unpublished data).

(b) Vegetation: The results are summarised in Table 2.

TABLE 2 - Summary of data.

	Site	% Basal cover	% Bare	No. species recorded
Mitchell grass (grey cracking clays)	1	3.0	53	15
	2	6.5	25	10
	3	4.3	56	19
	4	7.0	33	21
	5	2.0	91	15
Eucalypt woodlands (red earths)	1	1.2	45	11
	2	2.0	54	16
	3	2.0	71	14
	4	2.7	67	11
	5	3.2	52	16
	6	2.5	57	17

TABLE 1 - Mean values and coefficients of variation %

		Bulk Density	pH	Total N %	Acid P ppm	Bicarb P	Repl. K	Exch. K meq/100g	% TSS	P %	Total K %	Total S %	CEC meq/100g	Ca++ meq/100g
1. Mitchell Grass Downs (cracking clays) Ug 5.22	Mean	0.74	8.1	.082	143	15.8	1.1	1.68	.028	.051	1.35	.027	56	48
	cv	12	3	21	40	25	20	16	13	27	5	21	10	8
2. Eucalypt Woodland "Desert" (sandy red earths Gn 2.12	Mean	1.53	6.7	.035	6	5	0.41	0.47	0.007	0.027	0.46	0.007	6	2.7
	cv	6	9	11	29	25	10	11	13	13	5	19	14	21

Discussion

(a) Soils: The results indicate the sampling technique was suitable for obtaining bulk density samples. Bulking of soil samples will be necessary to obtain mean values for nutrients at a particular site.

(b) Vegetation: The results indicate for sampling at that time of the year, % bare is a good indicator of "condition".

Basal cover for the *Astrebla* grasslands varied 2.0 to 7.0% and averaged 4.6%.

Basal cover for the eucalypt woodland, ranged 1.2 to 3.2% and averaged 2.3%. These variations could be attributed to grazing intensities, seasonal rainfall and time of sampling. Basal cover figures tend to be related to soil type, with higher values obtained on the heavier textured soils.

Potential use of rangeland inventories

We are presently sampling on a fixed grid pattern. Sampling is done at 20 000 m grid points determined by the Australian metric grid. All sites are suitably marked so they can be easily re-located by other research workers. We are using 1:250 000 LAND SAT (1973) imagery as an aid in compiling the inventories. The inventories could be used in conjunction with LAND SAT imagery for short term or seasonal monitoring of the open *Astrebla* grasslands. Quantitative measurements of vegetation (basal cover, yield) would be necessary to establish a relationship with spatial signature. This relationship could then be used to monitor the effects of management practices.

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STABILISATION OF DUNES BY SANDHILL CANEGRASS

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Abstract

Changes in cover afforded by sandhill canegrass (*Zygochloa paradoxa*) have been studied on a low dune near Menindee in western New South Wales for 23 years. Areal cover of live and dead culms has varied in accordance with rainfall conditions, from 5.0 to 19.9% during the study period. Despite the low cover and an extended 4-year drought, the dune has not been changed significantly in profile by erosion during that time.

The plant is a perennial drought-evading species that actively grows in response to above-average rainfall conditions and dies back during drought. Changes in cover during the trial were mainly related to changes in clone size rather than to fluctuations in the plant population. In the last 18 months of the trial new plants established in response to the favourable rainfall conditions.

Introduction

Sandhill canegrass (*Zygochloa paradoxa* (R. Br.) S. T. Blake) is an important stabilising plant on sand dunes in the arid and semi-arid areas OF Eastern Australia (Black, 1960; Specht, 1972). It is generally confined to the crests of the deeper sand dunes, lunettes and sand ridges and is found in and around the Simpson Desert, extending through south-western Queensland and western New South Wales to north-western Victoria (Blake, 1941). In southern areas it is more commonly found as small discontinuous colonies on light coloured, unstable sand dunes associated with old lakes and river systems.

It is a glabrous, dense, spreadingly branched, dioecious hummocky perennial grass that grows to 1.5m in height and diameter. Its stout rhizomes, dense bushy habit and high resistance to drought make it an excellent sand binder (Blake, *op cit*; Ratcliffe, 1937). Jessup (1960) has described how canegrass accumulates mounds of soil blown by wind from between the plants.

Sandhill canegrass is not an important pasture plant. It is only slightly palatable to sheep (Ratcliffe, 1937; Jessup, 1951), but is said to be eaten by cattle (Blake, *op cit.*). However, Ratcliffe (1936) reported a great reduction in sandhill canegrass following drought in the Birdsville Track region and attributed death to damage of the roots caused by rabbits burrowing under the clumps.

At Lake Menindee in western New South Wales serious wind and water erosion has occurred on the lunette in areas where the natural vegetation (including mainly sandhill canegrass) has been removed to establish recreation areas. These areas require expensive and time consuming reclamation techniques to restabilise them (S.C.S. unpublished data).

To understand more fully the growth habits and protective role of this important sandbinding plant, the Soil Conservation Service of New South Wales commenced observations in 1953 on sandhill canegrass growing on a low dune in an exclosure 16km north-west of Menindee.

The Study Area

The trial was established on a low sand dune behind the Lake Menindee lunette. The soils in the area consist of light red-brown sands on the dune crests with compact calcareous cloddy loams on the flats.

The dunes have a relief of less than four metres and are orientated in an east-west direction. The shoulders and flats are severely scalded and loose sand and "blow-outs" occur near the crests of the dunes.

The area is treeless with the dune crests being dominated by clumps of sandhill canegrass and the flats by black bluebush (*Maireana pyramidata*). The lower stable slopes of the dunes support both sandhill canegrass and black bluebush.

Average annual rainfall for the area is about 225mm and rainfall is highly variable with no seasonal pattern of distribution.

The study area, which was part of a stock route, was fenced out prior to the commencement of the project. The commencement of the study also coincided with the demise of the rabbits in the area due to the initial spread of myxomatosis in the district. The area has remained ungrazed except for two periods between 1970 and 1972 and 1974 to the end of the trial when rabbits were uncontrolled due to fence maintenannce difficulties.

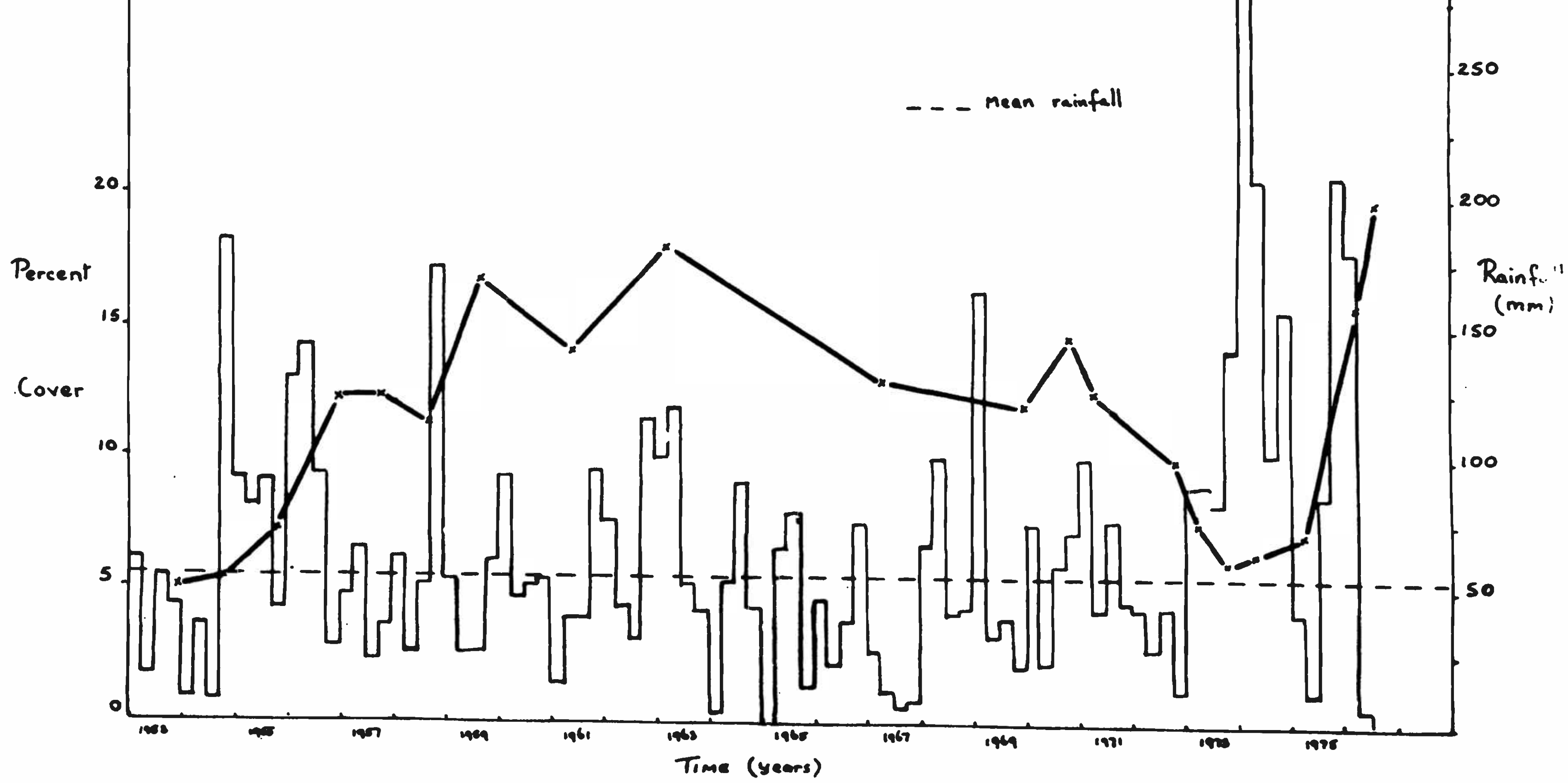
Methods

Plant Cover

Areal cover of sandhill canegrass was measured along a belt transect (65m long and 5m wide) running over the crest of the dune. Each side of the transect was marked at 5m intervals with 1.27cm diameter steel rods and cover was determined by plotting the area covered by each plant within or overhanging the transect. The plots were made on 2.54cm^2 graph paper with each square representing a 5m^2 section of the belt transect. This allowed quick, reliable recordings of plant shape and size to be made as well as accurate estimates of areal cover.

Twenty observations were made between November 1953 and August 1976 at intervals of between six months and four years.

Figure 1:- Percentage Ground Cover of Sandhill Canegrass and Seasonal Rainfall



Soil Stability

Changes in dune profile which reflects soil stability, were monitored by two line transects along each side of the belt transect and measured by stadia survey of peg tops as well as measuring the height of each peg above the soil surface. Soil accumulation gives a relatively shorter peg length and vice versa for soil loss.

Eight observations were made during the period between 1961 and 1976.

Results

Plant Cover

The percentage areal cover of canegrass along the transect at each observation during the trial is shown in figure 1. Also shown is rainfall during the period grouped seasonally into three monthly totals commencing with summer rainfall (January-March). The areal cover and number of clones of canegrass present at each observation is tabulated in table 1.

During the trial canegrass cover ranged from a minimum of 5.0% at the commencement of the trial in 1953 to a maximum of 19.9% in 1976. During the 23 years of observations there were five periods of increase in cover and four of decrease.

Figure 2 shows each individual plant or clump of plants along the transect at selected observation periods. These periods were the troughs and peaks of cover by canegrass. In plotting plants it was observed that during drought conditions the above ground parts of the canegrass plant (culms and leaves) died back but still persisted for several years. When conditions were favourable growth recommenced from basal buds and from buds along the culms at the periphery of the dormant plant.

In April 1974, during an extended wet period several plants were recorded as "dead," and although most of these plants later re-shot, at least one had definitely disappeared by the following year.

During 1975-1976 there was a large increase in areal cover from the canegrass, this being due partly to increase in clone size but also due to the large establishment of new plants (see figure 2).

Soil Stability

Due to the long term nature of the project and the method of measuring soil accumulation or loss small differences were not regarded as important. Small errors were regarded as inherent to the method due to errors in stadia readings and peg height measurements. The presence of litter accumulations and the angle of repose of sand around the base of the peg gave small differences at each reading (when comparing heights, differences between readings of less than 2cm were regarded as insignificant).

The profiles across the dune along each side of the transect at 1961 and 1976 are shown in figure 3 and figure 4.

Discussion

Plant Cover

Correlation between plant growth and seasonal conditions is not

TABLE 1

PERCENTAGE AERIAL COVER AND NUMBER OF CLONES OF SANDHILL CANEGRASS ON THE TRANSECT

Date	% Cover	No. Clones
Nov. 1953	5.0	27
Oct. 1954	5.4	29
Oct. 1955	7.3	29
Dec. 1956	12.3	20
Oct. 1957	12.4	23
Sep. 1958	11.4	32
Aug. 1959	16.8	25
May 1961	14.2	33
March 1963	18.2	23
April 1967	13.0	31
Dec. 1969	12.0	25
Oct. 1970	14.7	25
April 1971	12.5	25
Oct. 1972	10.0	24
March 1973	7.6	29
Oct. 1973	6.1	22
April 1974	6.4	26
March 1975	7.1	40
March 1976	15.9	31
Aug. 1976	19.9	35

ZYGOCHLOA PARADOXA TRANSECT
1953 – 1976

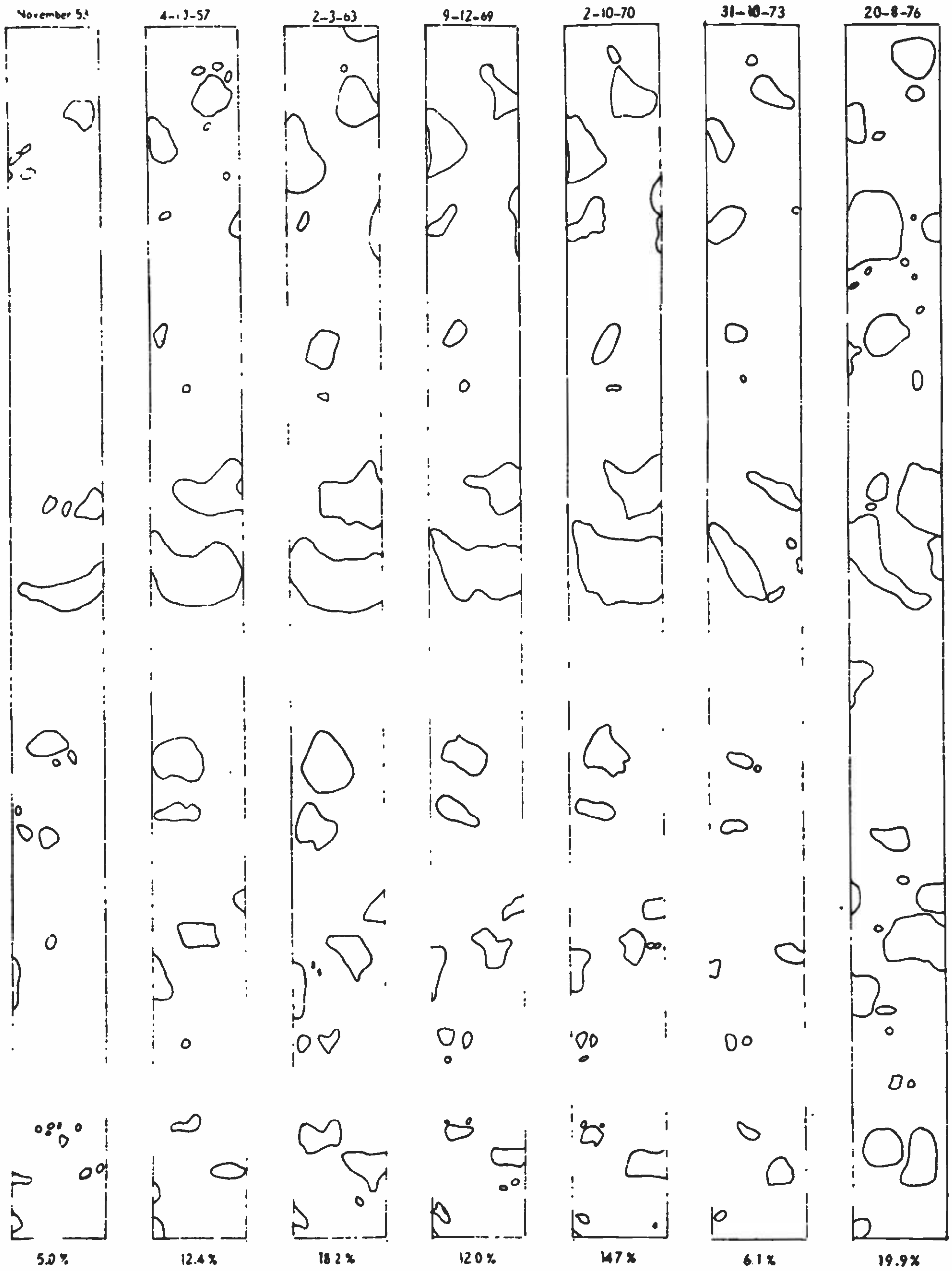


Figure 2 :– GROUND COVER

Figure 3 :- Changes in Dune Profile with Time (Transect A)

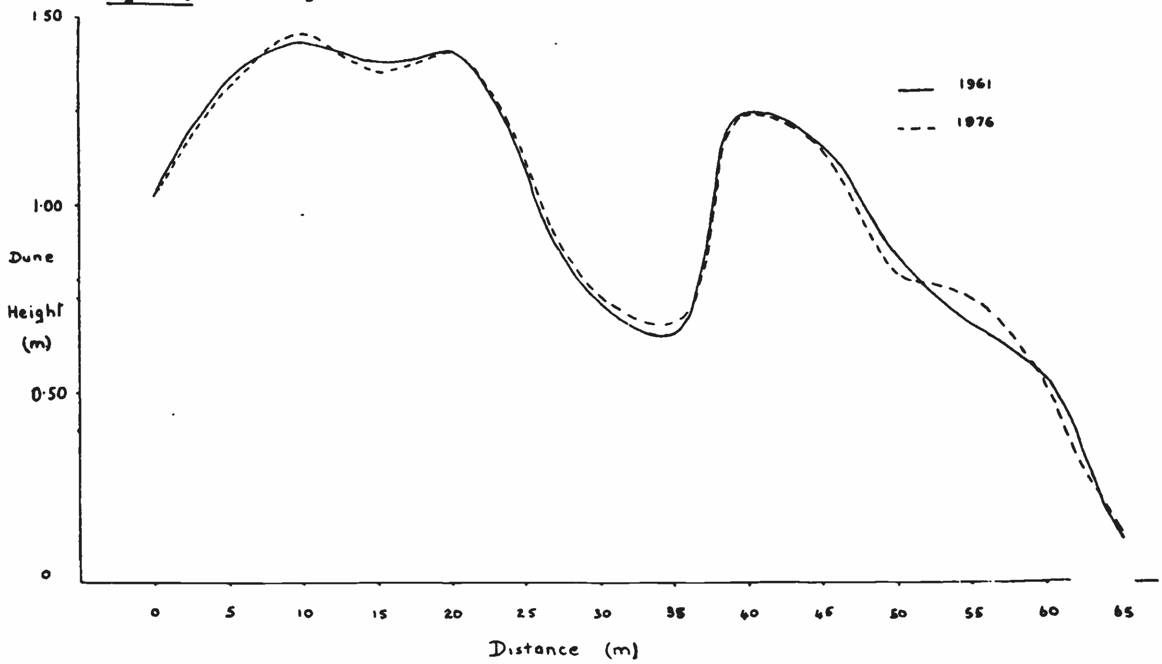
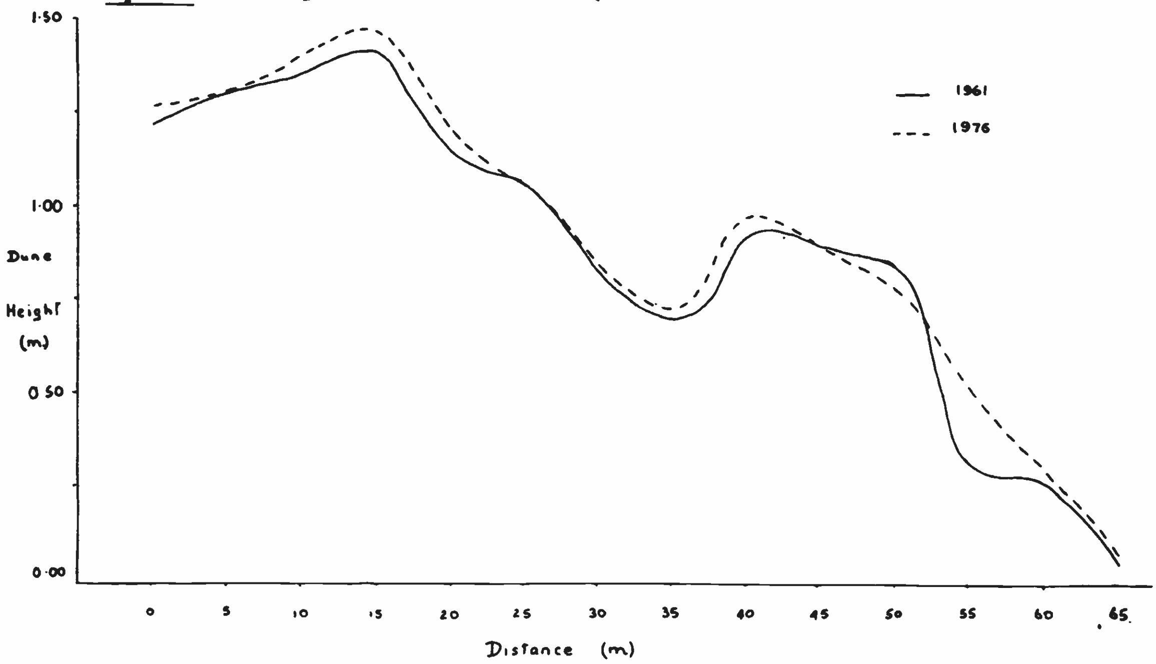


Figure 4 :- Changes in Dune Profile with Time (Transect B)



easily made because observations were generally made at intervals of one year or more. However, it appears that increases in plant cover occurred during periods when rainfall was well above average, and that decreases were related to average to dry rainfall conditions.

The first increase in cover occurred during the period from October 1954 to September 1956 when rainfall was well above average.

The second, third and fourth periods of increase in cover followed good spring and/or summer rain.

The final increase in cover may be divided into two sections. The final increase in cover may be divided into two sections. The first involved an increase of only 1.0% in transect cover between October 1973 and March 1975, despite the fact that 864mm of rain fell during this period, including a record of 766mm for Menindee in 1974. The second involved a large increase of 12.8% in cover between March 1975 and August 1976, during which time 500mm of rain was recorded.

Spring/summer rainfall was very high in both periods, but whereas in the second period autumn/winter rainfall was average, it was almost three times above average in the first. As sandhill canegrass is a summer grower and favours well-drained soils, it appears that in exceptionally wet autumn/winter periods it may suffer from "wet feet," growth is inhibited and death of plants may also occur.

Because of its growth habit, changes in cover during the period have generally been related to change in size of individual plants or canegrass clumps, rather than to an increase or decrease in plant numbers except in the latter period.

Soil Stability

The dune profiles have remained relatively stable throughout the trial.

The profile along peg transect A has changed very little. Greatest loss was nearly 5cm at the 50m peg, and the greatest gain nearly 7cm at the 55m peg. There has been no change, or slight accumulation of soil at all except the 50m peg along transect B, where between 5 and 6cm of soil has been lost. Greatest accumulation was 20cm at the 55m peg.

The 50 to 55m pegs are on the northern slope of the dune where erosion by water and strong north and north-westerly winds is most likely.

The most significant feature of the profile is that during the extended dry period from 1964 to 1967 virtually no soil loss or accumulation took place even though sandhill canegrass was the only species providing protection to the dune, however from 1967 to 1969 a blow-out occurred between pegs at 55 and 60m and accumulation occurred at the 50m peg in transect B.

Conclusion

In the absence of grazing it appears that areal cover of land between 5 and 20% by sandhill canegrass will offer reasonable protection to dune crests from wind erosion in all but prolonged drought conditions.

Canegrass offers little protection to the soil from water erosion and soil loss can be expected following heavy storms.

The establishment and spread of canegrass is heavily reliant on infrequent favourable climatic conditions. However, once established the plant is highly persistent in dry times and offers protection to the soil. It tends to disappear during wet periods, particularly in autumn-winter periods.

The restabilisation of eroded land once vegetated and protected by canegrass can be expected to be a long process, even in the absence of grazing animals.

Acknowledgments

The contribution of Mr. J. W. Lawrie in all aspects of the work is gratefully acknowledged.

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THE EFFECT OF CLIMATE AND GRAZING BY RABBITS ON SURVIVAL AND GROWTH OF BLACK BLUEBUSH *MAIREANA PYRAMIDATA* SEEDLINGS AT MENINDEE IN WESTERN NEW SOUTH WALES

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Abstract

The effect of climate and grazing by rabbits on black bluebush *Maireana pyramidata* seedlings growing on sand dunes and scalded loam flats was studied over a four-year period near Menindee, N.S.W.

Drought conditions which prevailed in the initial six months of the study greatly reduced seedling numbers irrespective of grazing. Subsequent drought periods had little effect on the survival of seedlings growing in ungrazed plots.

A flash flood devastated almost the entire seedling population of one plot.

Despite severe grazing by rabbits during three dry periods some seedlings, although completely defoliated, showed a remarkable ability to recover.

During the second dry period rabbits greatly reduced the shrub population on the dunes by scratching out plants, but had little effect on plants growing on the scalded loam flats.

Rabbits showed a preference for the woody parts of the bush, which affected size, growth rate and fruiting of plants.

Results show that post germination climatic conditions are important for plant establishment but that rabbits can also significantly reduce establishment of black bluebush seedlings, particularly on areas with coarse-textured soils. Black bluebush which covers extensive areas of this soil type in western New South Wales, offers protection to the soil from wind erosion.

Introduction

Black bluebush (*Maireana pyramidata* Benth) is the largest of the Australian *Maireana* species (Leigh, 1972), growing to a height of almost 2m and to a diameter of almost 3m on sandy soils (S.C.S. unpublished data).

It is a long-living, drought resistant native perennial shrub common over much of western New South Wales, and in South Australia. It grows as almost monospecific shrub communities, or in association with other bluebushes, or perennial saltbush (*Atriplex vesicaria*). It is also a common shrub component of mallee, belah-rosewood and mulga communities (Leigh, op. cit.).

Although black bluebush is one of the least palatable bluebushes it does provide some stock feed during drought. However, heavy grazing and ringbarking by sheep and rabbits in dry times have removed black bluebush from large tracts of country on the Riverine Plain (Leigh and Mulham, 1965).

Beadle (1948) records that rabbits are particularly fond of bluebush areas because digging is easy and succulent green feed is readily available. He suggests that rabbits rather than sheep may be responsible for the disappearance of *Maireana* spp. in areas of western New South Wales.

Because black bluebush is a long-living, drought-resistant plant which grows on coarse-textured soils susceptible to wind erosion, it is extremely valuable for soil protection (Beadle, op. cit; Leigh and Mulham, op. cit.).

Results of studies conducted on the establishment and growth of black bluebush at Menindee (Milthorpe, unpublished) showed a need for more data regarding the impact of climate and rabbit grazing on seedling establishment. In 1972 a trial was commenced to isolate the effects of climate from rabbit grazing on bluebush seedling survival.

The Study Area

The study site is located 16 km north-west of Menindee on land immediately behind the Lake Menindee lunette. This land consists of alternating sandy rises or dunes, with alkaline sandy soils, and scalded flats, with compact calcareous loam soils.

In 1953, a regeneration area was established on part of a stock route to study the effect of grazing on the natural vegetation. In this study plots were established both inside and outside the regeneration area.

The area is treeless with the dune crests being dominated by clumps of sandhill canegrass (*Zygochloa paradoxa*) and the flats by black bluebush (*Maireana pyramidata*). The lower, stable slopes of the dunes support both sandhill canegrass and black bluebush.

Average annual rainfall for the area is about 225 mm and rainfall is highly variable with no seasonal pattern of distribution.

Methods

The trial examined the effects of climate in the presence and absence of grazing on the growth of black bluebush seedlings on two soil types, loamy sands and calcareous loams.

Inside the regeneration area ungrazed plots were located on the slope of a low dune and on an adjacent scalded flat. Each plot was fenced with rabbit-proof netting.

Unfenced replicate plots were established outside the regeneration area and were open to grazing by rabbits and domestic stock.

Each plot measured 8.23 m (27 feet) by 4.57 m (15 feet) and was divided into 45 x 0.914 m^2 (1 square yard) quadrats.

Seedlings in the original population were marked by wire pegs placed beside each plant. When plants died the pegs were removed.

Seedling counts were made 15 times between August 1972 and August 1976, at intervals of 2 to 6 months.

In August 1976 a random sample of 25 bushes from the original population in each plot (or all bushes when there were less than 25 plants remaining) was selected and the height and diameter of each bush measured. In addition all other plant species on each plot were harvested for determination of dry matter yield.

Results

Data on the survival of the original and later populations, and on average plant density, are presented in Table 1 and shown in Figures 1 and 2.

Between the second and third observations flooding of 80% of the flat killed most of the seedlings on the ungrazed plot but although partially flooded there was little effect on plants on the slightly higher grazed plot.

TABLE 1 - Black Bluebush Population and Density Data

	3.8.72	23.10.72	22.2.73	30.4.73	18.6.73	28.8.73	31.10.73	16.4.74	16.8.74	13.11.74	20.3.75	17.7.75	31.10.75	27.2.76	6.8.76	Total Average Plant Density (Pl/m^2) 3.8.72	6.8.76
UNGRAZED DUNE																	
Original Population	459	335	210	200	184	177	173	173	172	172	172	172	172	172	172		
Later Populations	-	17	10	21	29	29	38	33	32	27	33	37	40	40	39	12.20	5.61
% of Original Population Remaining	100	73	46	44	40	39	38	38	38	38	38	38	38	38	38		
GRAZED DUNE																	
Original Population	540	398	206	189	162	158	157	140	132	130	87	76	75	75	75		
Later Populations	-	97	32	43	43	40	39	21	19	16	11	6	11	11	9	14.35	2.23
% of Original Population Remaining	100	74	38	35	30	29	29	26	24	24	16	14	14	14	14		
UNGRAZED FLAT																	
Original Population	294	129	*12	10	6	6	6	6	6	6	6	6	6	6	6	*80% flooded and plants lost	
Later Populations	-	8	1	0	0	4	3	3	3	3	8	8	7	7	10	7.82	0.43
% of Original Population Remaining	100	44	4	3	2	2	2	2	2	2	2	2	2	2	2		
GRAZED FLAT																	
Original Population	298	126	53	46	35	34	32	31	31	29	28	28	28	27	27		
Later Populations	-	7	5	6	6	18	20	35	27	23	25	25	26	27	26	7.92	1.41
% of Original Population Remaining	100	42	18	15	12	11	11	10	10	10	9	9	9	9	9		

FIGURE 1 :— Survival of Grazed and Ungrazed Black Bluebush with Time.
Original Population

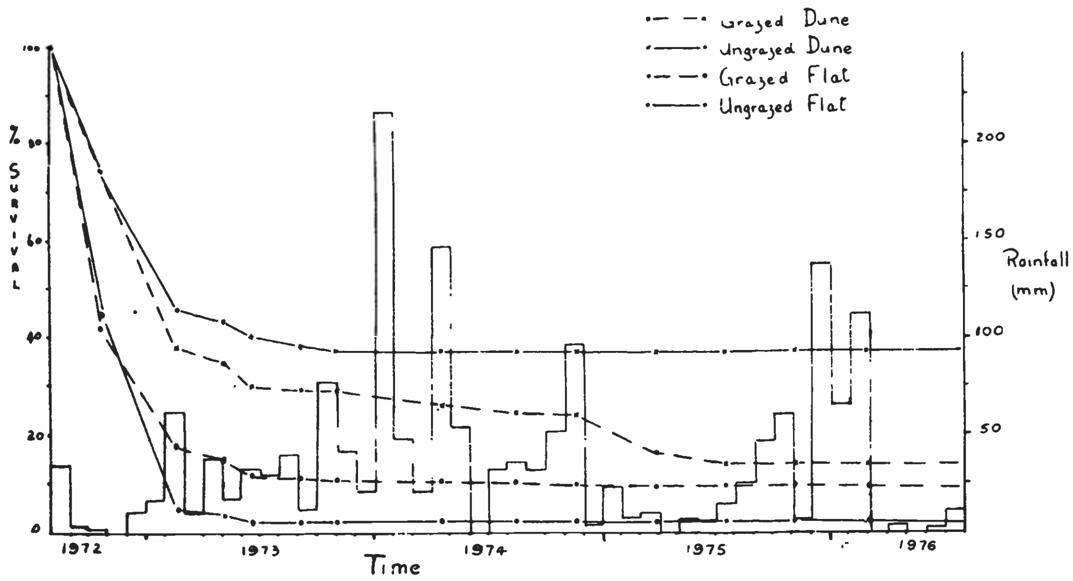
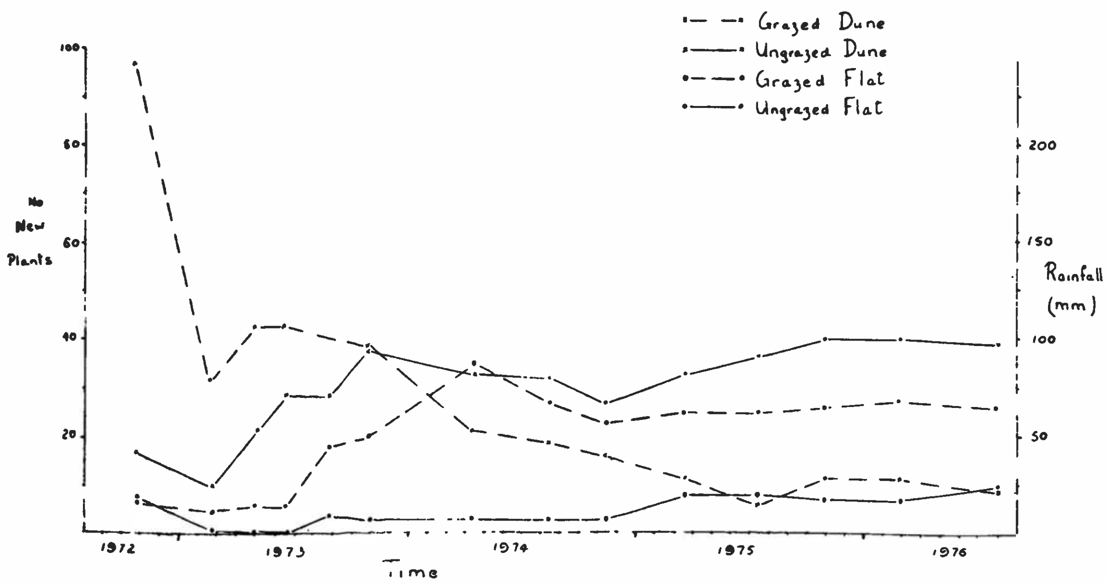


FIGURE 2 :— Survival of Grazed and Ungrazed Black Bluebush with Time.
Subsequent Populations



During the second and third dry periods bushes throughout the area were severely grazed. The following evidence indicates that rabbits were responsible for almost all the grazing on the outside plots.

(i) Lack of evidence of grazing by domestic stock (sightings, tracks, dung) but evidence of rabbit activity in the area (sightings, warrens, scratchings, dung).

(ii) Neatly chewed twigs and stems on all bushes, cut off at an angle of approximately 45° which is characteristic of rabbit browsing.

(iii) The abundance of uneaten leaf discovered at the base of grazed bushes supports Graetz (1973) comment that rabbits prefer to nibble the stems rather than the foliage of black bluebush.

(iv) Rabbits require green feed during dry periods and black bluebush and sandhill canegrass (*Zygochloa paradoxa*) provided the only green material during dry spells, while domestic stock prefer annuals and perennial grasses even when dry and these were abundant throughout the trial.

During the second dry period several plants on each of the grazed plots were completely defoliated and only short "stumps" remained. On the dune site some bushes were so heavily grazed that they could not be found. Comments on field sheets for many plants such as "heavily grazed, rabbits"; "eaten by rabbits"; "black bluebush scratched out" were made at the March and July 1975 observations.

At the end of July favourable rainfall conditions returned and in October 1975 many of the "stumps" on the flat, and some on the dune, had re-shot.

Table 2 shows average height and diameter of 25 randomly selected bluebushes, and the dry weight of other plant species on each plot.

TABLE 2 - Size of Black Bluebush and Dry Matter Yield of Other Plant Species, August 1976

	Black Bluebush Dimensions (cm)		Dry Matter Yield (gm)		
	Average Height	Average Diameter	Sandhill Canegrass	Other Species	Total
Ungrazed Dune	30.2	33.8	3290	4890	8180
Grazed Dune	15.0	20.8	140	4380	4520
Ungrazed Flat	78.7	147.3	570	1360	1930
Grazed Flat	23.1	27.9	-	1320	1320

The ungrazed plots each had a greater diversity of plant species than their respective grazed plots. Despite this difference in composition, production of species other than bluebush or sandhill canegrass was almost the same for each grazed and ungrazed site, however canegrass yield varied greatly due to grazing.

The first flowering and fruiting of bushes was recorded during August 1976. Six bushes were flowering or fruiting on the ungrazed dune, one on the grazed dune, but none on either the grazed or ungrazed flat.

Discussion

The Original Population

Death in all original populations showed a remarkably similar pattern during the first 15 months of the trial. In this period reductions in plant numbers were mainly due to the interaction of climate and competition.

The rapic rate of decline in all populations to February 1973 corresponded with the first dry period, and between February and October of 1973 there was a much slower death rate which corresponded with above average rainfall conditions.

This supports Milthorpe (unpublished), who suggested that survival of black bluebush seedlings may be markedly affected by the climatic conditions immediately following plant establishment.

The population numbers had stabilised after 15 months on all sites except the grazed dune. Unfortunately flooding prevented comparison between the grazed and ungrazed flats, but on the dune grazing appeared to have reduced the population during this initial period compared with the ungrazed site.

During the extremely wet period from October 1973 to November 1974 the population declined slightly on the grazed dune. In the dry period that followed large numbers of plants died at this site due to the effects of rabbits. However, on the flat rabbits were unable to dig at the roots of bushes and only one death was recorded.

During the dry period at the end of the trial there was no record of rabbits scratching at the roots of bushes, and no deaths occurred.

The percentage of the original plants surviving at the end of the trial on the grazed dune was about one third that surviving on the ungrazed dune, which strongly suggests that rabbits are an important factor in controlling black bluebush numbers on sandy soils.

Subsequent Populations

Later populations showed behaviour in response to climate and grazing similar to that of the original population: increases and decreases in population size were closely related to rainfall conditions; flooding again killed seedlings on the ungrazed flat; populations declined or were static during the record rains of 1974 but increased in the following dry period, except on the grazed dune where there was a large decrease due to the effect of rabbits; the heavily grazed stumps of "dead" plants again re-shot after effective rainfalls; and rabbits again had a greater influence on plant numbers on the dune than on the flat due to their ability to dig in the loose sandy soils.

Effects of Grazing on Bush Growth and Seeding

Grazing of black bluebush by rabbits resulted in a distinctively smaller densely bunched bush compared with ungrazed bushes which were relatively much larger and more open.

In the grazed plots bushes were larger on the flat than the dune, and in the ungrazed plots were much larger on the flat than the dune.

A black bluebush plant growing through the rabbit-proof netting at the ungrazed flat was grazed on one side but not the other. This bush had a heavy cover of immature fruit on the ungrazed half, and almost no fruit on the grazed half, suggesting that rabbits either inhibit fruiting or eat and dislodge the fruit when grazing. This explains the greater number of fruiting bushes recorded on the ungrazed dune.

Effects of Grazing on Other Plant Species

The results as shown in Table 2 suggest that after a 5 month dry period the rabbits are heavily reliant on perennial species for forage and appear to be largely dependent on sandhill canegrass and black bluebush for food despite abundant dead ephemeral forage. This was further endorsed by the abundant visual evidence of rabbit grazing of both perennial species.

Conclusion

For the successful establishment of black bluebush seedlings favourable climatic conditions for a period of at least 6 months is critical but grazing by rabbits during these dry periods can further markedly reduce seedling populations.

Plants establishing on compact loam soils stand a better chance of survival due to the inability of rabbits to dig out the roots. However, plants on sandy soils are extremely vulnerable to "rogueing" by rabbits.

As most of the extensive areas of bluebush country in western New South Wales is notoriously bad "rabbit country" it would be expected that at least 18 months of continuous favourable climatic conditions are required for the successful establishment of black bluebush.

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APPEARANCE OF NEW SPECIES IN PASTURES AT TRANGIE IN CENTRAL-WESTERN NEW SOUTH WALES

G.E. Robards and D.L. Michalk

Introduction

Numerous lists of plant species, ranging from excursion notes to ecological surveys, have been published in New South Wales during the last one hundred years (Pickard 1972). The more detailed of these documents contain an increasing list of plants in later years due to both the identification of native species and the spread of exotic species. For example, when Moore and Betcke (1893) published their list it contained 243 species, including 24 grasses. However, even by 1939 Anderson had compiled a list of 415 naturalized species other than grasses, and Cross and Vickery (1957) added a supplementary list of 57 naturalized grasses. Also, Vickery (1950) published a list of 366 native grasses.

In agricultural areas some exotic pasture plants may be introduced to improve the feed available for domestic livestock, and some species which spread into an area may be more productive than the native species. However, many exotic species, introduced either intentionally as garden plants or unintentionally in stock fodder or packing material, have become weeds in the agricultural sense. The spread of these plants either by fodder or stock movements, by wind or water, or on clothing or rubber tyres, has resulted in a continuously changing flora in most areas. Examples of such change have not been examined in detail in the literature.

This paper presents a list of plants collected within a grazing experiment at Trangie between 1967 and 1974, which do not appear to have been present in the area about twenty years earlier. The possible importance of some of these species to existing plant communities and to agricultural production is discussed.

Procedures

Site

Plants were collected at Trangie between 1967 and 1974 from within the bounds of a sheep grazing experiment. They were identified by checking against a herbarium collection at Trangie, or in the case of unknowns and doubtful specimens were sent to the National Herbarium, Sydney. Initial results and botanical observations from this experiment were presented by Campbell, Saville and Robards (1973). The experiment was conducted on two soil types, 100 hectares of red-brown loam (40 ha sown to dryland lucerne) and 20 hectares of grey, self-mulching clay. The predominant vegetation alliance is *Eucalyptus popilnea* with co-dominants of *Callistris hugelii* and *Casuarina cristata* (Beadle 1948; Biddiscombe 1963). Dryland cropping has been widespread throughout the area since about 1910 on light soils, but there was a marked increase about 1960, and irrigation farming developed markedly after 1970.

Comparisons of Botanical lists

The list of plants compiled during the grazing experiment from 1967 to 1974 was compared to the ecological surveys of Beadle (1948) and Biddiscombe (1963) for the corresponding vegetation alliance. A comparison was made also with the comprehensive list prepared on Bundemar Station, Trangie by Clark (1948). Thirty five plants which occurred in our collection but were not reported in any of the three earlier publications are listed in Table 1. These plants are relisted in Table 2 in terms of their potential as weeds. The assessment of weed status was made by examining publications by Maiden (1920), Moore (1960), Whittet (1968) and our own assessment of the role of the plants in the Trangie environment and agricultural forms.

Discussion

The plants listed here were collected from only a very small area in comparison to the total area of the *Eucalyptus populnea* vegetation alliance in the Trangie district as described by Beadle (1948) and Biddiscombe (1963). Therefore we are almost certainly conservative in reporting an addition of 35 plants to the earlier lists which had an average listing of 180 species. Nevertheless, the increase is substantial considering that it occurred in little more than twenty years. No doubt some of the species may have been present in very low numbers and so missed by the earlier collectors. Certainly some species were not far outside the area, as Cambage (1905) recorded *Argemone ochroleuca* and *Goodenia pinnatifida* near Gilgandra. In contrast to their wideranging observations, our detailed studies allowed us to add to our list species which we only sighted occasionally as isolated plants, namely *Phalaris minor, Anguillaria dioica, Polygonum prostratum, Rumex tenax, Chenopodium polygonoides, Hirschfeldia incana, Goodenia pusilliflora, G. pinnatifida, G. subintegra* and *Brachycome campylocarpa.*

There are no doubt many and complex means (Michael 1970) by which the plants invaded the Trangie pastures. The first could be that the natural pastures had been disturbed (Moore 1960) in such a way that invasion was easier after about 1948 than it had been before then. As a result of disruptive forces such as drought, fire, flood, rabbits and overgrazing by sheep and cattle (Breakwell 1918; Wheller and Hutchinson 1973; Williams 1973), pastures in the Trangie region certainly had changed from the original diverse mixtures of perennial grasses. Biddiscombe (1953) placed particular emphasis on severity of grazing as a principal factor in changing pastures in the Trangie region towards annual dominance and weed susceptibility. From Biddiscombe's description the light soil area on which our study commenced in 1967 was markedly degraded as it was completely dominated by annual species. Similarly, from their description the area of pasture on the heavier soil may have been in an advanced stage of degradation because the perennials which dominated the area were predominantly *Chloris acicularis* and *C. truncata.* Grazing pressure may have contributed to any expansion in the area of annual dominated pastures (Campbell, Saville and Robards 1973) relative to that present when Biddiscombe and his collegues carried out their studies between 1948 and 1953 (Biddiscombe 1953; Biddiscombe *et al* 1956). This can be concluded because despite a marked increase in dryland cropping during the period, stock numbers remained relatively constant and therefore grazing pressure on natural pastures must have increased (Robards and Michalk 1976).

A second factor operating after 1948 would be the increased rates and distances associated with transportation. The increase in rubber-tyred motor vehicles entering the area, and the greater mobility of stock and fodder, could all have been responsible for the rapid introduction of seeds from anywhere in south-eastern Australia. Further factors in the spread of seeds would be the increased extent of cropping and the development of irrigation channels and banks.

Of the plants more often observed and therefore either established for longer or more suited to the environment, most can be discribed as potentially important weeds (Table 2). Not only have they been described as such by Moore (1960) and Whittet (1968), but also nine of them were listed by Maiden as early as 1920. In fact, five were listed by Maiden (1920) as being among the twenty most undesirable weeds in New South Wales up until that time.

Further examination of our complete botanical list shows that the fifteen species listed in Table 2 almost doubles the number of potentially severe weeds recorded at Trangie by 1974. The other main species are *Aristida spp, Bassia birchii, Bassia quinguecuspis, Carthamus lanatus, Cryptostemma calendula, Emex australis, Erodium spp, Hordeum leporinum, Malva parviflora, Marrubium vulgare, Muehlenbeckia cunninghamii, Sisymbryum irio, S. orientale, Solamum nigrium, Stipa spp, Tribulus terrestris, Xanthium chinese* and *X. spinosum.*

If pasture conditions due to grazing pressure, particularly following dry periods, is a major factor in the spread of new species into the Trangie area, then graziers may be able to restrict the spread of weed species already in the area and prevent future invasions by the way they manage their pastures. If however, seeds are entering the area in greater numbers due to the movement of stock, fodder, irrigation water or rubber tyred vehicles, and becoming established regardless of pasture condition, then further botanical changes will almost certainly occur. The appearance of such undesirable species as *Cenchrus pauciflorus, Cirsium vulgare, Salvia reflexa, Senecio jacobaea,* and even *Cardus pycnocephalus, Centaurea calcitrapa, C. solstitialis, Cucumis myriocarpus* and *Lactuca serriola* seems inevitable.

TABLE 1 - Plants collected from natural pastures at Trangie between 1967 and 1974 which had not been reported previously.

Botanical Name	Common Name(s) *
Gramineae	
Bromus molliformis	Soft brome
Bromus unioloides	Prairie grass
Digitaria sanguinalis	Summer grass, Crab grass
Enneapogon nigricans	Nigger-heads, Black heads
Phalaris minor	Lesser Canary grass
Liliaceae	
Anguillaria dioica	Early Nancy
Polygonaceae	
Acetosella vulgaris	Sorrel
Polygonum prostratum	Creeping knotweed
Rumex crystallinus	Shiny dock
Rumex tenax	a native dock
Chenopodiaceae	
Chenopodium polygonoides	
Amaranthaceae	
Alternanthera pungens	Khaki weed
Papaveraceae	
Argemone ochroleuca	Mexican poppy
Cruciferae	
Brassica tournefortii	Wild turnip
Geococcus pusillus	Earth cress
Hirschfeldia incana	Hairy bassia, Buchan-weed
Raphanus raphanistrum	Wild radish
Rapistrum rugosum	Turnip-weed
Convolvulaceae	
Convolvulus arvensis	Bindweed
Dichondra repens	Kidney-weed
Boraginaceae	
Echium plantagineum	Paterson's curse, Salvation June
Labiatae	
Salvia verbenaca	Wild sage
Solanaceae	
Datura stramonium	Common thronapple, Caster-oil plant
Solanum sodomaeum	Apple-of-Sodom

Table 1 continued..

Botanical Name	Common Name(s) *
Goodeniaceae	
Goodenia pusilliflora	Small-flowered Goodenia
Goodenia pinnatifida	Cut-leaf Goodenia
Goodenia subintegra	Silky Goodenia
Compositae	
Brachycome campylocarpa	Large White Brachycome
Calotis scapigera	Tufted burr-daisy
Chondrilla juncea	Skeleton-weed, Naked weed
Cirsium vulgare	Spear thistle, Black thistle
Conyza bonariensis	Flax-leaf fleabane
Hedypnois rhagodioloides	Cretan-weed
Helipterum variable	Yellow paper-daisy, Golden sunray
Silybum marianum	Variegated thistle, Milk thistle

*
Common Names mostly correspond to those in 'Pastoral Plants of the Riverina Plain' by J.H. Leigh and W.E. Mulham (1965).

TABLE 2 - Weed status of the plants which have appeared in the natural pastures at Trangie.

Botanical Name	Recorded by Maiden 1920	Listed by Moore 1960
Plants which may be a problem under some circumstances		
Acetosella vulgaris	*	*
Alternanthera pungens	*	*
Argemone ochroleuca	*	*
Brassica tournefortii		*
Hirschfeldia incana		*
Raphanus raphanistrum	*	*
Rapistrum rugosum		*
Convolvulus arvensis	*	*
Echium plantagineum	*	*
Salvia verbenaca	*	*
Datura stramonium	*	*
Solanum sodomaeum	*	*
Chondrilla jucea		*
Cirsium vulgare		*
Silybum marianum		*
Plants of only a minor weed problem		
Bromus molliformis		
Bromus unioloides		
Digitaria sanguinalis		*
Phalaris minor		
Goodenia pusilliehora		
Goodenia pinnatieida		
Goodenia subintegra		

Plants not regarded as weeds.

All other plants listed in Table 1.

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RUNOFF FROM NATURAL AND SIMULATED RAINFALL IN THE MULGA COMMUNITIES OF SOUTH WESTERN QUEENSLAND

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Abstract

Surface runoff in the mulga (*Acacia aneura* F. Muell.) lands of south western Queensland was recorded from small plots using both natural and artificial rainfall. Runoff was higher from the hard mulga and dissected residual land zones than from the soft mulga zone. Runoff was positively correlated with surface slope, soil bulk density and the fine sand component of the soil, and negatively correlated with plant dry matter, canopy cover and basal area, litter, and the coarse sand soil component. Emphasis is placed on the importance of maintaining adequate plant cover to reduce the deletarious consequences of surface soil and nutrient loss.

Introduction

The mulga (*Acacia aneura* F. Muell.) lands of Queensland may be classified as 1) Mulga Sand Plains 2) Soft Mulga 3) Hard Mulga and 4) Dissected Residuals (Dawson et al 1975). These authors state that the sand plains are stable, but the hard mulga and residuals are naturally unstable, and are made more so by misuse. Top feed has been reduced on the hard mulga and erosion of the soil surface has particularly occurred on those areas adjacent to more productive ones. Runoff is high on the residuals due to shallow soils and rocks, and steep slopes.

Although the soft mulga zone is stable in its natural state, mismanagement has lead to a reduction in ground cover, loss of soil, and an overall decrease in productivity. However, mulga regeneration on such areas is possible with sound management, and it is also possible the biomass of pasture may increase, although by which species is not clear.

It is generally agreed that water flow on the soil surface may be arrested to some degree by plant material (standing dry matter and litter), but it is increased through soil compaction by stock, and slope, among others. The work presented here was designed to study the effects of topographical, soil and plant variables on surface runoff in the soft mulga, hard mulga, and dissected residual land zones of south western Queensland. Preliminary results have been published previously (Pressland 1976a).

Materials and Methods

Two approaches were used in the measurement of runoff from small plots. Firstly, a number of permanent small runoff plots were installed from which surface runoff was collected and recorded following rain. Secondly, artificial rainfall was applied to small plots until a fixed quantity of runoff was recorded. The results from both methods were used to associate runoff with one or more topographical, soil, or vegetative features using correlation and regression analysis.

Permanent Runoff Plots

Twenty four micro-catchments were installed in the soft mulga zone under four densities of open mulga woodlands - 40, 160, 640 and 4000 trees ha^{-1} - as well as on areas cleared of mulga, both burnt and unburnt. A detailed site description was published previously (Pressland 1976b). The catchments were 2.4 m long and 1.2 m wide. At the down-slope side was a covered triangular concrete apron with an outlet hose leading to a 45 litre container. The plot walls were constructed of either galvanised iron or wood so that about 10 cm was below and 8 cm above ground level. The design was a modification of that described by Costin et al (1960). The soil was non cracking so walls 10 cm below ground level were considered adequate.

Runoff from each catchment was generally recorded following each fall of rain, although on a few occasions a number of events contributed to a single runoff recording. Rain was recorded from a rain-gauge placed within 10 m of the plot. Runoff was recorded from November 1972 to January 1974.

At the end of the period the soil and vegetative characteristics of the plots were measured. Soil bulk density in the 0 to 3 and 3 to 6 cm soil layers were estimated from five soil cores in each plot, except that in the five plots under 640 trees ha^{-1} bulk density of the 0 to 3, 3 to 4, and 4 to 7 cm soil depths were recorded. Soil strength was estimated from 20 readings with a soil penetrometer.

Basal area of the vegetation was recorded either from five line transects or direct measurement of the circumference of grass tussocks and forb stems with a flexible steel tape.

Canopy cover of the vegetation was estimated visually by two men working independently.

Standing dry matter was harvested two centimeters above ground level, dried in a forced draught oven and weighed.

Soil surface litter was swept off the ground surface and washed and dried before being weighed.

Surface slope over the area was less than one percent. Neither mulga tree density nor burning was included as a variable in the analysis.

Runoff from Artificial Rainfall

Two square frames one metre on side and 30 cm high were constructed from 6 mm armour plate steel. One side of one frame was equipped with four evenly spaced exit pipes 12.5 cm in diameter and situated 10 cm from the bottom. The second frame had a horizontal slit 6 mm wide cut along one side 10 cm from the bottom over which was welded a piece of 19 mm pipe on the outside of the frame. A Length of polyethelene pipe led from each exit to a 10 litre container which when filled from the 1 m^2 plot contained the equivalent of 10 mm of water.

Initially the frames were hammered into the ground to the level of the exit pipes, but because of rocks, in most instances it was necessary to dig a narrow trench into which the frame was fitted and the earth tamped tightly around. A hole was dug for the 10 litre container so water could gravitate into it from the enclosed surface.

Water was applied through a modified shower rose from a 1360 litre tank using a 4 hp Briggs and Stratton motor connected to an unmodified sheep jetting pump, of 38 mm inlet and 12.5 mm outlet. Rate of application was maintained as close as possible to 100 mm h^{-1}, although on a few occasions the rate fell to 85 mm h^{-1}. The shower rose was clamped into position 20 cm above ground level so a vertical stream of water was applied upwards which subsequently fell to the ground with a terminal velocity of 7.1 m sec^{-1}, similar to natural rainfall (Smith and Smith 1950). Water from either a household tank or a farm dam was used to minimise the effects of salts present in the more readily available bore water.

A galvanised pipe frame three metres square and three metres high and covered with canvas was erected around the plot to minimise the effects of wind. It was necessary to tie the frame down with guy ropes in gusty conditions.

Water was applied until the collection container was full or for 90 minutes whichever occurred first. The period of application was measured with a stopwatch. The application rate was checked at the start and completion of the run. Runoff was expressed either as a percentage of water applied, or as time taken for 10 mm of water to run off.

Sixteen sites were selected for runoff determination, 10 in the soft mulga zone, and three each in the hard mulga and dissected residual zones. At each site runoff from six plots was recorded. The position of each plot was selected so that a range of pasture biomass between least (usually none) and most was recorded.

At the completion of runoff recordings at each site, the following details of each plot were recorded:

1. Bulk density of the 0 - 3 and 3 - 6 cm soil depths were estimated from three samples using a 5 cm diameter core sampler.

2. Standing dry matter of vegetation was clipped as close to the ground as possible. The vegetation was oven dried and shaken to remove soil particles before being weighed. No attempt was made to separate living from dead material.

3. Surface litter (decaying vegetation, sticks and animal faeces etc.) was collected, oven dried and sieved to remove soil particles, separated into vegetation and faeces, and wood, and weighed.

4. The percentage ground surface covered by the base of plants (basal area %) was recorded as the length of plant base intercepts on six line transects across the plot, three parallel to each side of the plot. Where only a few plants were growing within the plot, the circumference of individual plant tussocks was recorded with a flexible steel tape.

In addition to the individual plot data, the surface slope of each site was recorded with a surveyor's theodolite and staff, and soil samples for mechanical analysis at each site were taken. Surface soil samples from within all plots at each site were thoroughly mixed. One hundred gram samples were taken and digested in a 5% hydrogen peroxide solution to remove the minimal organic matter. Coarse sand (2.0 - 0.2 mm) was separated by passing the soil suspension through a sieve, and the silt and clay fractions (0.02 - 0.002 mm and less than 0.002 mm respectively) were found by the hydrometer method. Fine sand (0.2 - 0.2 mm) was found by subtraction.

Runoff was recorded from soil which was air dry to a depth of at least 30 cm (determined visually), although runoff was collected from a few plots one day after the soil was wet to 30 cm.

Results

Permanent Runoff Plots

The soil and vegetation characteristics of the permanent runoff plots (Table 1) show the low vegetative biomass, basal area % and surface litter typical of the mulga understory. Soil bulk density is high ranging from 1.36 gcm^{-3} to 1.59 gcm^{-3} in the 0 - 3 cm layer, and from 1.47 gcm^{-3} to 1.57 gcm^{-3} in the 3 - 6 cm layer. The bulk density at depths of 3 - 4 and 4 - 7 cm of the plots under 640 trees ha^{-1} are in most cases much higher than those of the other plots.

The soil strength data were too variable (Table 2) to be used in the correlation analysis. Coefficients of variability (standard deviations %) as high as 73% were found within plots under dry soil conditions. Strength recordings on dry soil were more variable than those on wet soil.

TABLE 1

Vegetation and soil characteristics of natural rainfall plots

Plot		Plant Canopy Cover %	Basal area %*	Dry matter (g)	Litter (g)	Soil bulk density ($g\ cm^{-3}$) 0-3 cm	3-4 cm	4-7 cm	3-6 cm
cleared	1	73	1.7 (0.7)	1390	700	1.47 ± 0.05	NA	NA	1.50 ± 0.02
	2	77	3.2 (1.2)	1330	500	1.48 ± 0.06	NA	NA	1.50 ± 0.08
	3	95	2.6 (1.1)	1110	740	1.38 ± 0.07	NA	NA	1.48 ± 0.10
	4	80	1.5 (0.8)	910	580	1.48 ± 0.07	NA	NA	1.55 ± 0.05
40 trees ha^{-1}	1	83	1.5 (0.4)	1800	900	1.50 ± 0.10	NA	NA	1.55 ± 0.09
	2	77	1.3 (0.6)	550	1210	1.42 ± 0.05	NA	NA	1.48 ± 0.10
	3	87	3.6 (0.8)	1060	1220	1.47 ± 0.05	NA	NA	1.51 ± 0.13
	4	70	1.0 (0.3)	940	550	1.48 ± 0.04	NA	NA	1.50 ± 0.11
	5	95	3.2 (0.8)	1690	830	1.44 ± 0.08	NA	NA	1.50 ± 0.07
160 trees ha^{-1}	1	18	0.7 (0.5)	230	280	1.52 ± 0.06	NA	NA	1.54 ± 0.06
	2	90	2.3 (0.8)	930	580	1.53 ± 0.06	NA	NA	1.51 ± 0.15
	3	30	0.7 (0.3)	200	500	1.52 ± 0.07	NA	NA	1.57 ± 0.05
	4	100	3.2 (1.3)	2000	1230	1.43 ± 0.09	NA	NA	1.49 ± 0.09
640 trees ha^{-1}	1	33	1.2	110	740	1.48 ± 0.08	1.51 ± 0.15	1.62 ± 0.05	NA
	2	10	0	0	550	1.59 ± 0.09	1.65 ± 0.09	1.64 ± 0.05	NA
	3	25	0.1 (0.1)	120	1290	1.46 ± 0.01	1.65 ± 0.04	1.65 ± 0.09	NA
	4	33	0.4 (0.2)	100	490	1.39 ± 0.05	1.72 ± 0.13	1.69 ± 0.10	NA
	5	22	0.3 (0.3)	100	670	1.52 ± 0.08	1.72 ± 0.08	1.60 ± 0.09	NA
4000 trees ha^{-1}	1	**	0	0	870	1.41 ± 0.07	NA	NA	1.47 ± 0.05
	2	**	0	0	1140	1.46 ± 0.11	NA	NA	1.56 ± 0.06
	3	**	0	0	860	1.41 ± 0.05	NA	NA	1.50 ± 0.12
	4	**	0	0	650	1.43 ± 0.08	NA	NA	1.50 ± 0.11
cleared & fired	1	15	0.5 (0.5)	430	40	1.47 ± 0.10	NA	NA	1.58 ± 0.04
	2	<5	0.1	0	0	1.36 ± 0.06	NA	NA	1.47 ± 0.12

* standard errors in brackets NA: not applicable

** these plots supported varying numbers of young trees

TABLE 2

Variability of dry soil strength of selected natural rainfall plots

Plot		Penetrometer reading* (kPa)	Standard deviation	Coefficient of variability (%)
cleared	1	6920	2960	43
	2	6100	3250	53
	3	5440	2670	49
	4	8940	3960	44
40 trees ha^{-1}	2	8870	2210	25
	3	8520	4320	51
	4	4620	1960	42
	5	6390	3340	52
160 trees ha^{-1}	2	7660	4680	61
640 trees ha^{-1}	1	4840	2380	49
	2	3350	2460	73
	3	7660	4680	61
4000 trees ha^{-1}	1	4810	3410	71
	2	11870	5210	44

*Mean of 20 readings

Runoff recorded from all plots following rain in excess of 10 mm is shown in Table 3. Runoff from some plots often exceeded the capacity of the container (45 litres), so it was necessary to use only those data which were complete in the correlation analysis. This lead to the analysis of data from only seven runoff periods. Litter and canopy cover were generally negatively correlated with runoff while basal area and dry matter were of lesser importance (Table 4).

Positive correlations between runoff and bulk density were found in most cases, but in only three instances was the correlation significant at $P<0.1$. In these three cases, the soil surface was wet from previous rain, and in two there was no associated significant correlation between runoff and vegetation characteristics (Table 4).

There is some evidence to suggest that correlations of vegetation parameters with runoff increased with rainfall aggregate. The absence of correlations between runoff and many of the plant/soil factors is probably due in part to the rain characteristics, particularly intensity, which although measured, was not relation to the runoff data in the analysis.

Artificial Rainfall Plots

The biomass of vegetation and litter was also low on the artificial rainfall plots, ranging from 0 to 1095 gm^{-2} and 0 to 760 gm^{-2} respectively. Wood litter on a few plots added up to 2800 gm^{-2} to the litter component. The biomass of both these components was greater on the soft mulga than hard mulga or dissected residuals. Plant basal area was also higher on the soft mulga (up to 21%), than on the hard mulga or residuals (up to 2.6%).

The degree of slope ranged from 0 to 5.7%, the lowest on the soft mulga and the highest being on the dissected residuals.

Bulk density of the soil was higher on the hard mulga and residuals than the soft mulga. Bulk density in the former zones were 1.73 (SD 0.15) and 1.73 (SD 0.12) gcm^{-3} respectively in the 0 - 3 cm and 3 - 6 cm depths, compared with 1.56 (SD 0.10) and 1.56 (SD 0.11) gcm^{-3} respectively in the soft mulga zone.

Fine sand fraction of the soil was higher in the hard mulga and residuals than the soft mulga (75%, SD 4%, compared with 70%, SD 7%), but the reverse was the case for the coarse sand component (12%, SD 4% compared with 20%, SD 6%).

Higher correlations between runoff and the topographical, soil and plant parameters were found under the artificial rainfall study than the natural rainfall one. As the correlations obtained when runoff was expressed as runoff % and time were similar, only the former are discussed. Runoff % was positively correlated with bulk density in the 0 - 3 cm soil profile ($P<0.01$), fine sand % ($P<0.01$), fine sand % ($P<0.01$) and slope % ($P<0.01$), and negatively correlated with dry matter ($P<0.01$), litter other than wood ($P<0.01$), dry matter + other litter ($P<0.01$), dry matter + wood ($P<0.05$), basal area % ($P<0.01$), and the coarse sand fraction of the soil ($P<0.01$) (Table 5).

TABLE 3

Runoff from natural rainfall plots at selected recording dates (litres)

Date	Plot	9/11/72	27/11/72	29/11/72	8/12/72	27/1/73	12/2/73	18/2/73	20/2/73	1/5/73	9/7/73	21/7/73	17/8/73+	2/10/73	9/10/73	19/10/73	27/10/73	8/11/73	24/11/73	14/12/73	10/1/74	14/1/74	31/4/74
Precipitation (mm)		13.5	102	19.5	10.3	22	82	165	42	40	32	38	38	19	34	22	18	20	48	26.6	71.2	54	64
Cleared	1	22.8	*	11.4	20.5	*	*	*	*	*	4.6	27	18.2	25	41	25	4.6	0.1	34.1	27	2.3	29.6	6.8
	2	4.6	6.8	2.3	6.8	3.4	13.7	*	45	6.8	0.1	4.6	0.1	0	0.1	0.1	0.1	0.1	2.3	20.5	10	14	13.5
	3	0	8	0	4.6	0.1	45	>91	29.6	9.1	0.1	0.1	0.1	0	0.1	0.1	0	0	4.6	2.3	0.1	6.8	0.1
	4	0	*	2.3	NA	33	*	>91	30**	*	0.1	0	0	0	0.1	2.3	0	0.1	13.7	6.8	3.5	33	9.1
40 trees ha^{-1}	1	0	22.8	0.1	0.1	21	*	*	*	29.6	4.6	4.6	1.1	2.3	9.1	2.3	4.6	0.1	0.1	14	5	14	0
	2	4.6	*	4.6	4.6	2.3	*	*	*	31.9	0.1	18.2	4.6	13.7	5	10	6.8	1.1	9.1	25	13.7	22.8	9
	3	4.6	NA	2.3	2.3	34.1	2.3	0.5	*	0.1	0.1	2.3	0.1	0	0.1	1.1	0.1	0.1	13.7	17	8	13.7	4.6
	4	0	4.6	0.5	0.1	2.3	4.6	11.4	0.1	4.6	0.1	2.3	1.1	0	0.1	0.1	0.1	0.1	9.0	3.0	3.5	11.4	2.3
	5	27	*	0.5	4.6	8.0	6.8	43.2	*	*	2.3	31.9	13.7	19	2.3	34.1	1.1	2.3	23.5	36.4	27	*	34.1
160 trees ha^{-1}	1	20.5	*	11.4	22.8	*	*	*	*	*	4.6	*	25	27	*	*	19	0.1	41	45	43.2	*	*
	2	4.6	*	2.3	4.6	18.2	4.6	*	*	18	4.6	9.1	15.9	0	41	27	4.6	0.1	4.6	30.5	22.8	*	34.1
	3	0	*	1.1	1.1	25	45	*	*	36.4	2.3	4.6	4.6	4.6	4.6	27	2.3	1.1	31.9	29.6	41	*	15.9
	4	0	4.6	0	0	1.1	4.6	25	45	0	0	0	0	0	0.1	0	0	0	2.3	4.6	2.3	4.6	5
540 trees ha^{-1}	1	0	11.4	0	0	22.8	*	*	45	*	0.1	18.2	0.1	0	2.3	2.3	0.1	0	15.9	4.6	9.1	*	31.9
	2	9.1	37	27	NA	28	*	*	*	NA	0.1	36.4	8	0	34.1	18.2	0.1	0	25	11.4	20.5	*	38.7
	3	0	NA	0	0	2.3	*	NA	45	13.7	0	0.1	0.1	17	0.1	0.1	0.1	0	2.3	25	5	NA	14
	4	2.3	45	0	0	14	45	*	12	45	0.1	2.3	0.1	4.6	15	2.3	0	0	22.8	25	5	45	0.1
	5	4.6	*	0.5	2.3	23.5	45	*	36.4	45	0.1	31.9	9.1	10	28	18.2	0	0.1	45	29.6	16	45	27
4000 trees ha^{-1}	1	0	*	0	0	3.4	*	*	*	18.2	0	0.1	0	0	18.2	2.3	0	0	0	27	6.8	45	22
	2	4.6	*	4.6	2.3	11.2	*	*	*	18.2	2.3	9.1	11.4	9.1	19	20.5	5	1.1	4.6	14	9.1	*	43.2
	3	2.3	9.1	0	1.1	6.8	45	*	20.6	15	0	4.6	3.4	0	18.2	9.1	0.1	0.1	25.5	12	2.3	29.6	14
	4	2.3	*	0.1	0.1	12	45	*	*	4.6	0	2.3	0.1	3.4	11.4	2.3	0.1	0.1	18	6.8	9.1	*	15.9
Cleared + fired	1	NA	*	NA	NA	NA	NA	*	45	9.1	0.1	22.8	4.6	2.3	1.1	0.1	1.1	0	*	21	41	45	*
	2	NA	*	NA	NA	NA	NA	*	45	36.4	4.6	NA	9.1	6.8	0.1	4.6	3.4	3.4	*	14	43.2	38.7	6.8

*exceeded 45 litre storage capacity ** collection tin upset; probably > than this

+ 15 mm 9/8/73; 7 mm 13/8/73; 16 mm 17/8/73 NA: not available

TABLE 4

Correlation coefficients between runoff and various soil/plant parameters for seven rainfall events

Rain (mm)	Date	Vegetation Characteristics Canopy cover	Basal area	Dry matter	Litter	Soil bulk density 0-3 cm	3-6 cm
22	27/ 1/73	-0.57**	-0.43+	-0.33	-0.76**	-0.02	-0.06
22	19/10/73	-0.27	-0.26	-0.24	-0.32	0.43+	-0.03
34	9/10/73	-0.28	-0.24	-0.22	-0.27	0.47*	0.13
38	21/ 7/73	-0.49*	-0.41+	-0.38	-0.42+	0.36	0.04
48	24/11/73	-0.67**	-0.55*	-0.48*	-0.75**	-0.14	0.06
64	31/ 1/74	-0.51*	-0.37	-0.38+	-0.54*	0.43+	0.15
71	10/ 1/74	-0.63**	-0.52*	-0.52*	-0.73**	0.21	-0.03
Overall		-0.61**	-0.50*	-0.45*	-0.69**	0.29	0.05

Significance is shown by:
+ $P<0.1$
* $P<0.5$
** $P<0.01$

The correlations of most interest are those of runoff % with soil bulk density and percentage sand, plant litter, dry matter and basal area %, and slope %.

The multiple regression analysis indicates that the functions which can be used most satisfactorily for runoff prediction in this semi-arid environment are the soil bulk density and the fine sand and silt fractions of the soil, plant dry matter and basal area, and litter. The relationship with the highest R^2 value and the smallest number of variables (indicated by the C.P. Statistic) is shown in Table 6, together with the relevant significance tests.

Discussion

Both methods of studying the effect of topographical, soil and plant parameters on runoff yielded similar results. The probability of runoff occurring is higher on soils of high bulk density, and ones containing a large percentage of fine sand and silt, than on soils of low bulk density, and ones containing a lower percentage of fine sand but an increased amount of coarse sand; plant litter and standing plant material suppress runoff, and areas of high plant basal area possesses lower runoff tendencies.

However, surface slope may have a marked effect on these generalities. There was no correlation between slope and quantity of dry matter upon it, but litter (apart from wood) was negatively correlated with slope. In other words, the greater the slope the less the litter. Observations show that surface litter is greater on areas of low slope and at the base of ridges or slopes. The lack of correlation between plant dry matter and basal area, and degree of slope, indicates that runoff is not likely to be reduced by improving the body of herbage growing on ridges in mulga country - areas which have a notoriously high runoff potential (Dawson and Boyland 1974). Rather, soil surface bulk density and slope % will tend to dictate the runoff potential of the hard mulga and dissected residual zones. It is therefore most unlikely that stock management on such areas will succeed either in improving pasture basal area and biomass or reducing runoff.

However, it is probably that stock management to maintain a basal cover of about 3% on the lower slopes and flats will result in less surface water movement and greater infiltration of rain water into the soil. The removal of standing plant biomass and litter through extended periods of over-grazing by domestic stock and wildlife (including insects), or by fire, will tend to increase runoff and together with increased wind and water erosion - particularly on the hard mulga land zones and dissected residual land zones - will inevitably lead to poorer conditions for germination and establishment of plants (Condon et al 1967). In particular, surface soil moisture, organic carbon, and nitrogen will be considerably reduced. Under such conditions, major changes to the soil surface conditions will be necessary to encourage increased soil water availability and thus plant growth. Ripping, ploughing and pitting are mechanical methods available to the grazier but in the present state of the rural sector, it is unlikely that such techniques are financially feasible even if the manpower is available.

TABLE 5

Correlation coefficient between runoff % recorded from artificial rainfall and the independent variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Bulk density 0-3 cm	1.00												
2 " " 3-6 cm	0.73	1.00											
3 Dry matter	-0.15	-0.04	-1.00										
4 Wood litter	-0.10	-0.13	-0.01	1.00									
5 Other litter	-0.44	-0.20	0.20	-0.05	1.00								
6 (3+5)	-0.16	-0.13	0.51	0.86	0.06	1.00							
7 (3+4)	-0.35	-0.14	0.84	-0.04	0.71	0.40	1.00						
8 Basal area %	-0.39	-0.28	0.59	0.14	0.20	0.43	0.54	1.00					
9 Slope %	-0.06	-0.11	0.06	0.18	-0.34	0.19	-0.15	-0.10	1.00				
10 Soil clay %	0.37	0.35	-0.22	-0.03	-0.30	-0.14	-0.33	-0.12	-0.05	1.00			
11 " silt %	-0.14	-0.37	-0.11	0.07	0.15	<0.01	<-0.01	<-0.01	-0.20	-0.03	1.00		
12 " coarse sand %	-0.40	-0.40	0.19	0.08	0.10	0.17	0.20	0.34	-0.19	-0.21	0.00	1.00	
13 " fine sand %	0.34	0.36	-0.14	-0.07	- 0.09	-0.13	-0.16	-0.31	0.27	0.03	-0.12	-0.97	1.00
Runoff %	0.33	0.07	-0.44	<0.00	-0.41	-0.23	-0.55	-0.60	0.32	0.07	0.15	-0.34	0.34

Values to be exceeded for significance at $P<0.05$: 0.22
$P<0.01$: 0.29

TABLE 6

Regression coefficients and significance tests of the best "compromise" equation relating runoff percent to plot variables

Variable	Regression Coefficient	S.E. of Coefficient	T
BD03	29.0825	13.2852	2.19 *
BD36	-23.7548	13.3896	1.77
DM+other litter	- 0.0161	0.0060	2.67 **
Basal area %	- 1.6716	0.4010	4.17 **
Slope %	1.9545	0.6607	2.96 **
Silt %	2.4024	1.1829	2.03 *
Fine sand %	0.3352	0.2020	1.66
B(0)	5.3041	20.2825	

R^2 = 0.56

R^2 (adjusted) = 0.53

C.P. statistic = 6.18

Analysis of Variance

Source of variation	DF	Sum of squares	Mean squares	Variance ratio
Regression	7	15356.2	2193.74	16.352 **
Residual	89	11940.2	134.159	

It is inevitable though that some deterioration of mulga landscapes will occur - if not from the extended periods of drought common in the mulga regions, then from the continuance, through financial necessity, of maintaining too many animals on too small an area for too long.

The multi-regression analysis showed that only 56% of the variation in runoff from the artificial rainfall plots could be accounted for by the physical variables measured, leaving 44% unexplained. Some of this may have been due to irregularity of the rate of water application (85 to 100 mm h^{-1}). However, as even 85 mm h^{-1} is high, it is not considered probable. Surface roughness, presence of rocks, and type of ground cover (e.g. tussock grasses compared with prostrate broad leafed herbs) may be important additional factors. Notes were taken on these factors, but they were considered to be too subjective to be incorporated in the correlation analysis. The inclusion of a grazing intensity factor may have also increased the percentage of explained variability in runoff, although Rauzi and Smith (1973), working in the rangelands of the U.S.A., found that the grazing intensity of cattle had no significant effect on water infiltration into some sandy soils. They did however, find that infiltration on other loam soils was greater under low (0.6 beasts h^{-1}) to moderate (0.8 beasts ha^{-1}) stocking than under heavy (1.4 beasts ha^{-1}) stocking.

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SURVIVAL OF SOME SEMI-ARID SHRUBS FOLLOWING WILDFIRE

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Introduction

In the summer of 1974-75 wildfires burnt 3.75 million ha of rangeland country in western New South Wales. Most of this was in woodland vegetation - mallee, belah or bimble box, where many of the shrubs form an inedible, undesirable component. In the bimble box and belah communities the density of shrubs has increased markedly in recent years and methods of control are now actively sought. One reason suggested for the increase in shrub density is a decreased fire incidence, so that it was of considerable interest to record the performance of these shrubs after a natural fire.

Study Sites and Methods

The study sites were selected within one or two weeks of the fires, mainly in December 1974 and January 1975, but also including isolated fires in April and August 1975. They covered a range of vegetation types and a wide geographical area from near Balranald in the south to Louth and Cobar in the north. Sites were chosen to give a variety of plant species, plant size and fire intensity. Within a defined area (300 to 1500 m^2) at each location, each shrub and tree was marked by a numbered metal tag and records taken of species, height, degree of burn, regrowth (if any) and the occurrence of seedlings. Similar observations were recorded on nearby unburnt areas, but these were not always available. Observations of shrub survival were made in May 1975 and February - March 1976.

Results

As may be expected only a few shrubs died in the control areas and these results are not included in this paper. Also excluded are results for all shrubs that retained any green leaves after the fires, as these, regardless of species, were similar to those of the controls.

Overall there was considerable difference between species in their recovery after fire. The order was white cypress pine (*Callitris columellaris*) 2% recovery, mulga (*Acacia aneura*) 16%, narrow-leaved hopbush (*Dodonaea attenuata*) 25%, punty (*Cassia eremophila* vars.) 40%, yarran (*Acacia homalophylla*) 87%, budda (*Eremophila mitchellii*) and turpentine (*E. sturtii*) both 89%.

Generally, the degree of burning had little effect on survival although the chances of recovery of the more susceptible shrubs, e.g. hop bush, were less when the plants were burnt down to the butt. However, this only occurred in isolated instances, when the shrub was adjacent to a source of prolonged heat, such as a burning log. The majority of the plants totally affected by fire fell into one of three categories - (1) all leaves scorched, (2) some leaves scorched, the rest burnt, (3) all leaves plus branchlets burnt.

Data are presented in Table 1 for three of the more common shrubs, turpentine, punty and hop bush, showing the survival of plants in two ranges of burnt/scorched ratio and three size classes. Results from plants in all three categories listed above are included.

In these observations the size of the plant also had little bearing on recovery, provided the plants were not seedlings. Regrowth occurred from the base of small (< 0-5 m high) plants to the same degree as in much larger plants, but the larger bushes had more sprouting along the branches, particularly in turpentine. On some occasions there was subsequent death of plants that had sprouted after the fire.

Seedling shrubs, which would have been completely burnt, were missed by these post-burn observations. At one site where the fire had been stopped at a break and an adequate control was available, counts of turpentine seedlings on transects covering 1470 m^2 which had emerged before the fire (approximately 1 yr old) showed a density of 21 plants/100 m^2 on the unburnt area, but only 8 plants/100 m^2 on the burnt area. This is a much higher proportion of deaths than for the mature bushes of this species.

Large differences in survival were recorded between sites, particularly with *Cassia* and *Dodonaea*. These differences could not be explained in terms of plant size or degree of burn.

Post-fire emergence of seedlings of both punty and hop bush was recorded. The incidence of these seedlings was erratic, varying between sites and across a site. The maximum density recorded was 4 plants/m^2 for hop bush, but the subsequent survival of these has not been followed.

Discussion

These results show that fire has a marked effect on the numbers of some woody species, notably white cypress pine, mulga, punty and hop bush, regardless of size. The use of fire to control punty and hop bush is possible, although further investigation is needed to determine the conditions that favour high mortality and the post-burn management that is needed to control seedling regeneration. This could involve particular grazing treatments, or further burning before the seedlings reach maturity. Other shrubs, notably turpentine and budda, are more fire resistant and burning would appear to be of little value in controlling established stands. Further investigation is needed of the effects of repeated fires as these may reduce the vigour of these shrubs and reduce their competitiveness with grasses. The results did suggest that burning was more successful in reducing young seedlings of these shrubs. Unusually wet conditions are required for germination and establishment of these species, so that whenever they occur grass growth is good and suitable for subsequent burning. Hence burning may also have a place here for controlling the spread of shrubs such as turpentine and budda.

Table 1. Effect of degree of fire damage and of plant size on survival of three shrub species

	Degree of burn (burnt/scorched ratio)				Plant size					
	0/100 - 50/50		51/49 - 100/0		< 0.5 m		0.5 - 1.0 m		> 1.0 m	
	No. plants recorded	Mean survival (%)	No. plants recorded	Mean survival (%)	No. plants recorded	Mean survival (%)	No. plants recorded	Mean survival (%)	No. plants recorded	Mean survival (%)
Turpentine	342	90 ± 3*	234	82 ± 6	57	78 ± 9	301	94 ± 3	267	88 ± 5
Punty	211	36 ± 8	111	41 ± 18	150	48 ± 21	69	26 ± 10	170	47 ± 10
Hop bush	314	29 ± 6	257	26 ± 8	162	28 ± 9	175	40 ± 7	259	27 ± 7

* Standard error between sites

EFFECT OF GOAT GRAZING, MECHANICAL SHRUB CLEARING AND EUCALYPT RINGBARKING ON RUNOFF AND SOIL WATER AVAILABILITY IN A WOODY SHRUB INVADED SEMI-ARID WOODLAND

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Abstract

Runoff and soil water have been measured on differently managed areas of shrub invaded semi-arid woodland near Coolabah, in north-western N.S.W. Measurements commenced in spring of 1975 and are continuing. Results to the end of 1976 are presented. With the exception of a very wet 10 day period in early 1976, when runoff results were lost, about 7% of rainfall ran off the mechanically shrub cleared country while 18% was similarly lost from the uncleared area. Runoff was much less from thicket areas than from the relatively more open inter-thickets. Some runoff from inter-thickets was shown to run on to, and to infiltrate the thicket soils. During an unusually wet period *c.*40% more soil water accumulated on the shrub-cleared country than on its exclosed or grazed counterparts, while a further 28% accumulated on that country where eucalypts were also ring-barked. Enhanced herbage production on the shrub cleared areas caused the extra accumulated soil water to be rapidly used following the onset of dry weather.

Introduction

Large areas of the originally open woodlands on the red soils in the eastern portion of the Western Lands Division of N.S.W. have been invaded by woody shrub species (Anon. 1969; Moore 1969, 1973).

Extensive sheet erosion of the bare areas between patches of woody shrubs is reputed to have occurred on undulating country. This suggests that a significant proportion of the rainfall incident on undulating country is lost as runoff. Measurements of runoff on undulating country at Cobar between May and November of 1968 showed that an average *c.*18% of the incident rainfall failed to infiltrate during that relatively short period (Anon. 1969). On the worst eroded country in the Cobar area it is considered by some that very little rainfall infiltrates into the eroded soils (Cunningham 1967). Cunningham (*loc. cit.*) states that on such country, most rain is lost as runoff to the flats where the combination of runon water and the seed it carries gives rise to a thick growth of seedlings of noxious scrub. At the same time, the resulting lack of seed, moisture and top-soil on the ridges makes colonization of bare areas very unlikely.

In such a semi-arid system it is most likely that there is strong competition between trees, shrubs and herbage for water. Consequently there is a need to study the utilization of water within the shrub invaded woodland and to quantify any effects that management manipulations may have on its availability. This need is highlighted by the fact that several of the management strategies actually recommended for this type of country (Anon. 1969) either depend on, or, will have a strong effect on the reallocation of water within the community. These proposed managements include ringbarking, clearing followed by the growing of a fodder crop, using water spreading techniques to develop the flat areas for fodder cropping and improved pastures (Cunningham 1975), and the contour furrowing of undulating country.

Consequently, a study was set up to a) document patterns of runoff and soil-water availability in a shrub invaded semi-arid woodland and b) quantify the effects of goat grazing, mechanical clearing of shrubs and ringbarking of *Eucalyptus populnea* (bimble or poplar box) on the above parameters.

Methods

The study is located on some of the differently treated areas which are part of a collaborative study by the CSIRO Division of Land Resources Management of the structure and functioning of, and the effect of perturbation on, a shrub invaded semi-arid woodland community near Coolabah in north-western N.S.W. (see also Harrington, this conference).

There are two replicates of the following four treatments

i) exclosed,
ii) goat grazed at 1 goat per 2 ha,
iii) shrub-cleared and goat grazed (1:2 ha), and
iv) eucalypt ringbarked, shrub-cleared and goat grazed (1:2 ha).

Shrub clearing was achieved by using a bulldozer to push out all shrubs and trees with a trunk diameter of less than 30 cm at a height of 1.5 m. Ringbarking was carried out by cutting deeply through the cambium of all trees left standing by the bulldozer. Deep ringbarking ensured loss of all leaf within 30 days. Eucalypt sucker regrowth is removed monthly. Treatments were applied during late summer of 1975.

A stratified sampling system for both runoff and soil-water was necessary to accommodate the strongly patterned vegetation distribution and microtopography of the area. The basic unit of vegetation pattern or "cell" (Harrington, unpublished data) is a mature eucalypt tree (usually *Eucalyptus populnea*) surrounded by a thicket of woody shrubs about 15 m in diameter, which is in turn surrounded by a sparsely vegetated inter-thicket area of usually between 20 and 50 m to the next thicket. The soil surface at the centre of the thicket areas are usually 20 cm above the average level of the surrounding inter-thicket, which in the area studied has an average slope of 1%.

In each of the four treatments in each replicate two representative cells were selected for study. Cells were selected on the basis of similar a) size of central eucalypt, b) thicket diameter, c) slope of inter-thicket area, d) position on the catena, e) depth to parent material and f) soil type.

Runoff is collected for measurement on only one of each of the two representative cells of each of the eight replicate-treatment combinations. A 22 cm galvanised iron strip is buried 10 cm into the soil to constrain the runoff from the thickets and also from the selected inter-thicket areas to flow into collecting troughs and thence into 1250 litre corrugated iron holding tanks set 60 cm into the ground. The average area of a thicket runoff plot is 100 m^2 while all inter-thicket runoff plots are 40 m^2. Thus the installations are capable of holding 12 and 31 mm of runoff respectively. When possible, the quantity of water in the tanks is measured and the tanks pumped out after each runoff event.

For soil water measurements a total of 15 neutron moisture meter (NMM) access tubes were installed in each cell, in three rows of 5 tubes each, radiating upslope, across the contour and downslope from the central eucalypt. The five access tubes in each row are located at i) 2 m from the eucalypt, ii) 5 m, iii) 10 m, iv) half way from the 10 m tube to the centre of the inter-thicket area and v) at the centre of the inter-thicket area. Thus a total of 240 tubes are monitored.

NMM access tubes were installed to bedrock in all cases. The rock was also drilled for a further 15 cm to allow the centre of activity of the NMM to be lowered to the bedrock level. Depth to bedrock was very variable, ranging from a minimum of 48 to a maximum of 118 cm. The average soil profile depth was 74 cm with 8% of soil profiles being shallower than 60 cm and another 8% deeper than 90 cm.

Readings were taken at approximately monthly intervals using a Wallingford NMM to count for 16 seconds at depths of 3 cm, 15 cm, and thence at 15 cm intervals, until the bottom of the hole was encountered, where a final reading was taken. As the meter is calibrated against the mean water content of 15 cm intervals (except for the 3 cm reading) it was thus possible to estimate soil water status to a depth of 75 mm below the surface of the bedrock. The NMM was successfully calibrated in the field for depths of 3, 15 and >30 cm. The proportion of variance of volumetric water content accounted for by the calibration regressions was 92, 97 and 83% respectively.

Results

During the period from the start of this study (1.9.75) to December 31, 1976, the total rainfall received at the site was 821 mm (Figure 1). This was almost double the expected value of *c*.445 mm (the median rainfall for the appropriate 16 month period at Byrock, some 25 km to the north of the experimental area, as calculated from Byrock median annual rainfall and adjusted for the extra period using Bourke consecutive month median information (Australian Water Resources Council 1968)). Of this rainfall, some 490 mm fell during the wet period of from early December 1975 to early March 1976, including 186 mm during the 9 day period of from February 23 to March 2, 1976.

Table 1. Rainfall and runoff from shrub cleared and undisturbed thicket and inter-thicket areas

Period	Rain (mm)	Runoff (mm)			
		Thicket		Inter-thicket	
		Cleared	Undist.	Cleared	Undist.
Sept. 1 to Nov. 30, 1975	103	1	1	4	11
Dec. 1, 1975 to Feb. 22, 1976	303	13	16	41	96
Feb. 23 to Mar. 2 (flood period)	186	?>12	?>12	?>31	?>31
Mar. 3 to May 31	10	0	0	0	0
Jun. 1 to Aug. 31	69	0	1	2	7
Sept. 1 to Nov. 30	116	0	1	2	13
Dec. 1 to 31, 1976	34	0	1	2	8
Total excl. flood period	635	14	20	51	135
Runoff as % of rainfall		2	3	8	21
Total incl. flood period	821	?>26	?>32	?>82	?>166

Table 2. Computed infiltration (mm) on Dec. 6, 1975 (Rainfall = 34 mm) for undisturbed areas without runoff plots

Transect	Distance from tree (metres)						
	2	5	10	18	27	L.S.D.(0.05) between distances	Mean
Upslope	39	32	25	12	13		24
Contour	32	27	20	15	12	8	21
Downslope	29	25	17	12	10		19
L.S.D. between (0.05) directions			7				3
Mean	33	28	21	13	12	5	21

Unfortunately, the flooding produced by the rainfall of Feb. 23 - Mar. 2 prevented personnel from reaching the site to measure and empty the runoff tanks. As all tanks overflowed, the only information available for this period is that runoff exceeded 12 mm on the thicket areas and 31 mm on the inter-thicket areas (Table 1). Apart from this unusual event, the percentage of total rainfall (635 mm) that was collected as runoff has been surprisingly low - 3% and 21% from undisturbed thickets and inter-thickets respectively and 2% and 8% for their disturbed counterparts.

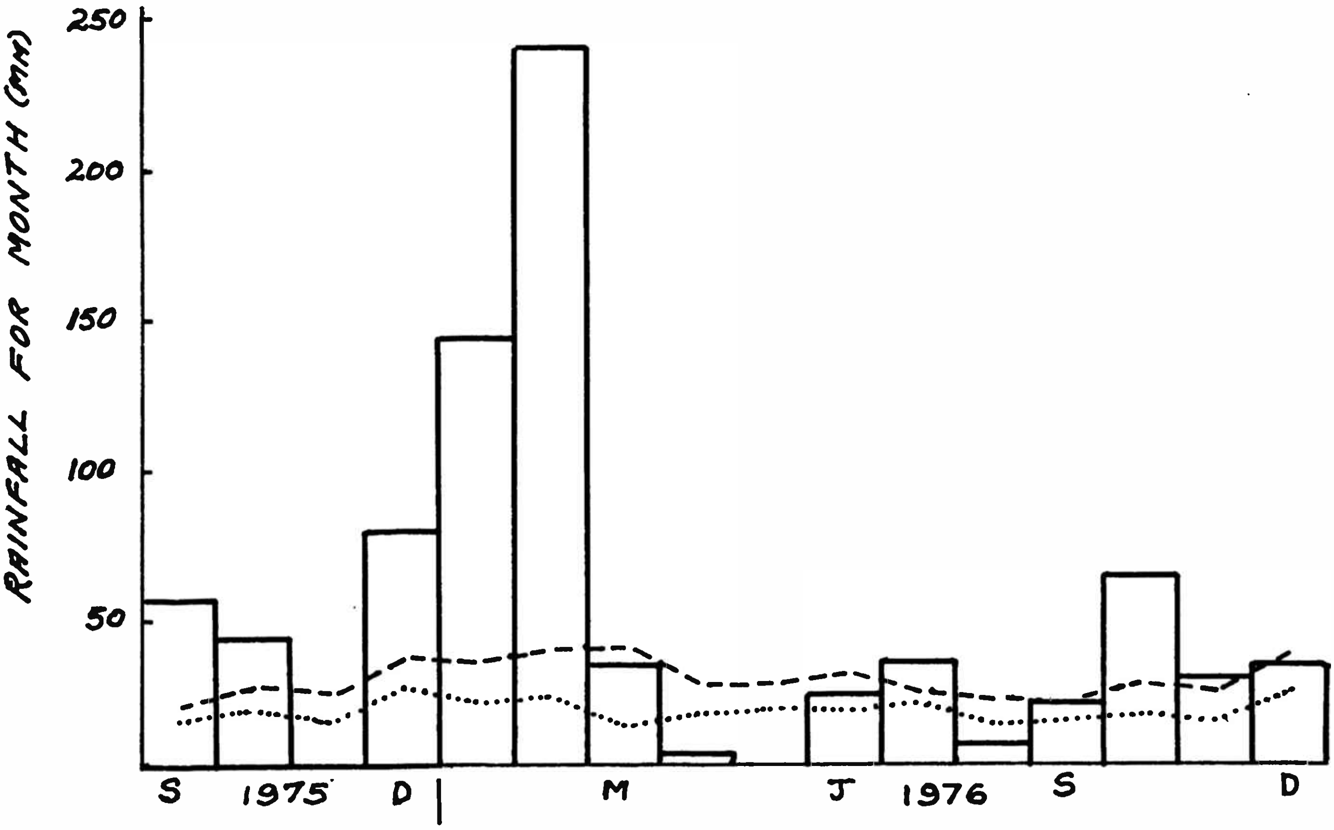

Figure 1. Monthly rainfall recorded at Coolabah site, and monthly means (----) and median (·····) for Byrock (70 year period).

Runoff percentages from individual storms were, of course, much greater than the above averages. On December 6, 1975, 34 mm of rain was recorded in just over two hours, with 28 mm falling during the first 40 minutes. During this storm undisturbed inter-thicket areas yielded up to 83% runoff, with an average yield of 63% while disturbed inter-thickets averaged 36%. In contrast, thicket counterparts yielded only 16% and 14% respectively.

As can be inferred from Table 1, many rainfall events produce negligible thicket runoff. During such events some of the runoff produced by inter-thicket areas has been found to run into the thickets where part of it augments the soil water status on the upslope side of the eucalypt. NMM measurements carried out three days after the storm of Dec. 6, 1975 showed that extremes of up to 90 mm infiltrated at some sites near the centre of thickets. Computed average infiltrations (mm) for undisturbed areas without runoff installations on Dec. 6 range from up to 5 mm in excess of the rainfall amount at 2 m upslope from the tree (Table 2) to 24 mm less at 27 m downslope.

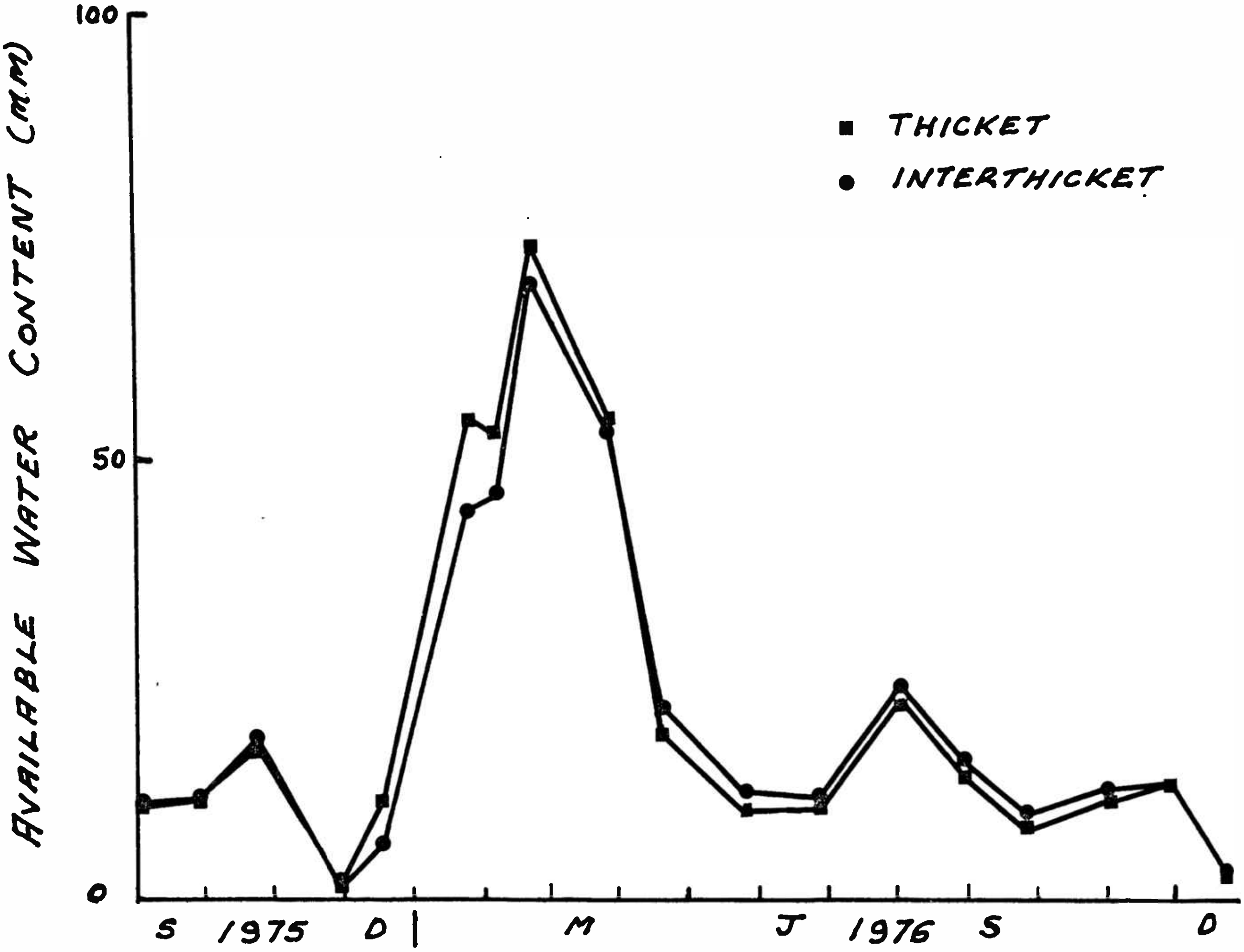

Figure 2. Available soil water content for thickets and inter-thicket areas. (Mean of all treatments).

The greater infiltration which occurs in the vicinity of the thicket appears to have caused more soil water to accumulate under the thickets during wet periods(Figure 2). During drier periods, however, the greater evapotranspiration associated with the greater biomass in the thickets caused the thicket soil profile to dry out to a greater extent.

The removal of the shrubs caused a 40% increase in available stored water during February, while prevention of eucalypt evapotranspiration by ringbarking caused a further 28% increase in available water at this time (Figure 3). Similar proportional effects were evident during other periods of the year.

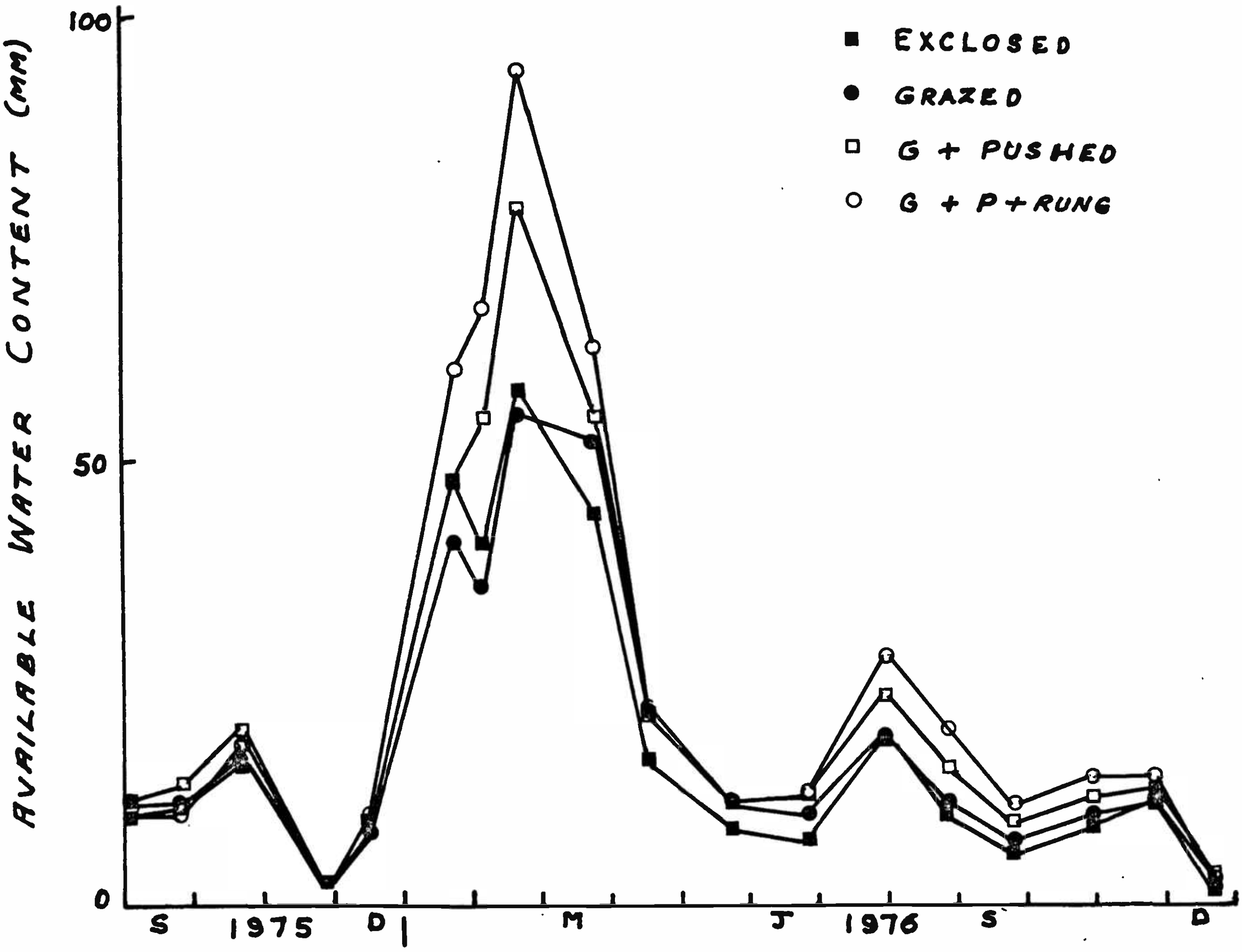

Figure 3. Influence of the four treatments on available water content.

The maximum quantity of available water that the Oakvale soil profile can hold is a very variable quantity, depending both on the amount of sand and gravel in the soil profile, and the depth to bedrock. NMM readings taken the day after the end of an extended wet period (February) indicate that on average the 0-7.5 cm zone holds 13 mm available water at field capacity and the 7.5-22.5 cm horizon holds 21 mm (Figure 4). The 22.5-67.5 cm zone has held 39 mm (March; probably, but not definitely at field capacity). The zone of variable thickness extending from 67.5 cm to 7.5 cm into bedrock (which ranges from 0-57 cm in thickness) has held anything from 0 to 103 mm of available water. Between November 1975 and March 1976, this zone gained available water as follows:

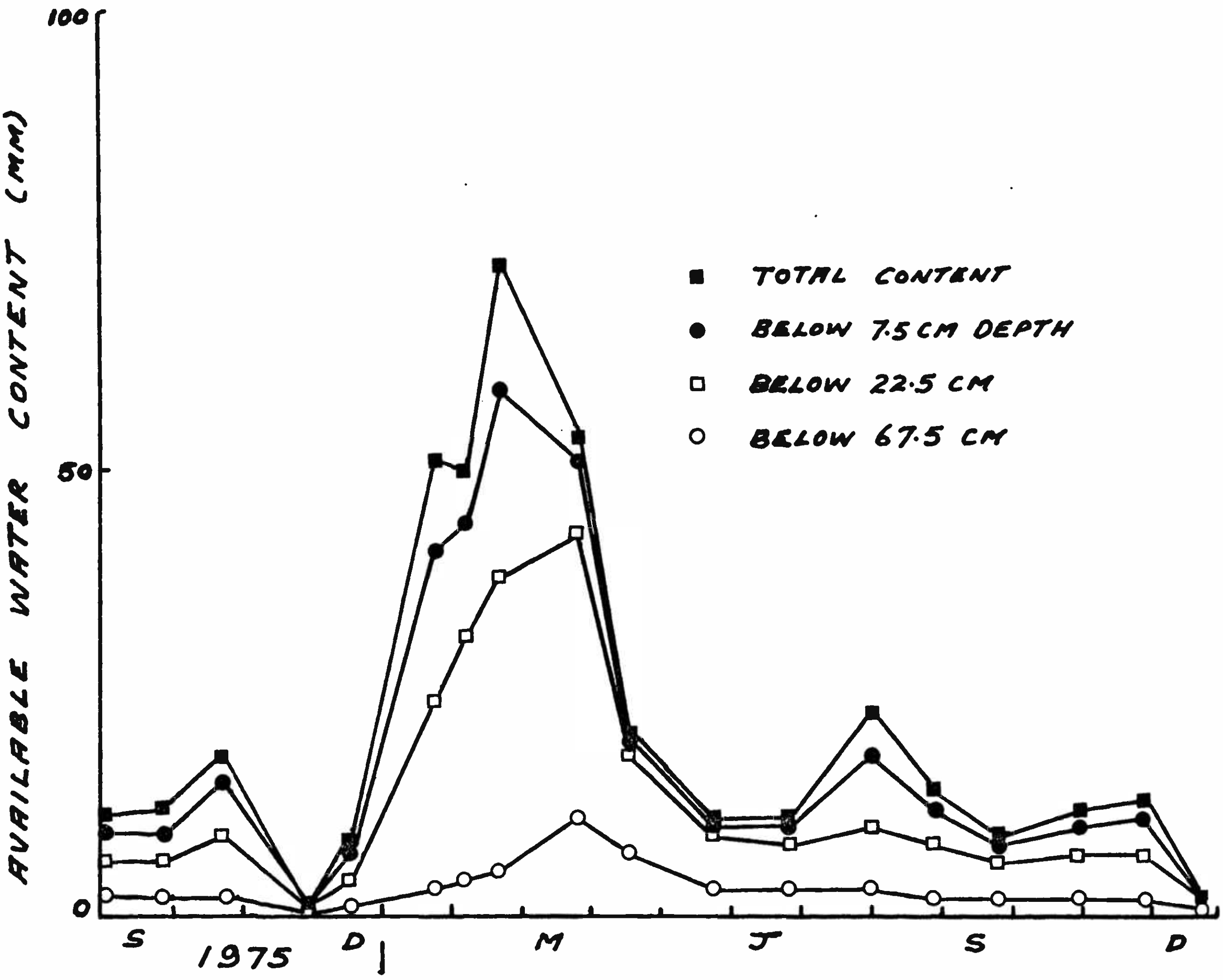

Figure 4. Distribution of available soil water within the soil profile. (Mean of all treatments).

gain of less than 5 mm	35%	of holes
5 - 10 mm	23%	
10 - 20 mm	27%	
20 - 40 mm	12%	
more than 40 mm	3%.	

The average quantity of water held in this zone after the prolonged wet period was 11 mm, to give an average total profile available water content of probably slightly in excess of 84 mm.

Discussion

To illustrate the unusually wet nature of the early part of 1976 at Oakvale, the total calendar year rainfall of 639 mm considerably exceeded the 90 percentile value of 564 mm for Byrock, while the 50 percentile Byrock annual value is 339 mm.

The failure to measure runoff during the very wet Feb. 23 - Mar. 2 period is unfortunate. However, it will be possible to estimate fairly accurately how much runoff there was by using the water balance model currently under construction. The model is being constructed to simulate the soil water availability under the eight combinations of the four treatments by thicket and inter-thicket. Such a model can be used in conjunction with the relevant soil water records to estimate soil water immediately prior to and following a rainfall event, and thus enable the estimation of runoff.

As yet the goat grazing treatment has had no detectable effect on soil water availability when compared to the exclosed control. While this is not surprising, the current rapid increase in the amount of mulga (*Acacia aneura*) growing on the exclosed inter-thicket areas may at some time in the future cause lower soil water availabilities on these areas.

In assessing the runoff figures there is a need to weight them according to the area represented to determine the average for a treatment. As thickets occupy about 15% of the area (Harrington, personal communication) the weighted runoff means for cleared and undisturbed treatments respectively are 7% and 18%. The large apparent reduction in runoff due to clearing will probably not be sustained; the effects of disturbance on both the sorptivity of the soil surface and perhaps more importantly surface detention will probably decrease with time under the influence of both trampling and erosional redistribution of soil. Runoff measurements will continue for at least another 24 months to detect and follow any such trends. The ramifications of the effect of clearing on runoff for *in situ* herbage production, stock water collection, erosion and any water-spreading or contour-furrowing development are obvious.

The tendency of runoff from inter-thicket areas to be absorbed by thicket areas is not as important in this system as in the banded mulga system documented by Slatyer (1961). This is because a) the thickets occur virtually at random, and b) the centre of thickets are usually about 20 cm higher than the average of the surrounding inter-thicket area. Thus runoff from areas except those immediately upslope of the thicket tend to run around the thicket rather than into it.

Part of the water in excess of rainfall that infiltrates immediately upslope of the eucalypt may be due to stemflow. However, significant differences obtained between thicket infiltration with and without runoff plot installation indicates that the galvanised iron border of the runoff plots has prevented surface water from entering the thicket.

The rapid usage of soil water by the disturbed treatments (Figure 3) during the autumn of 1976 was most probably due to evapotranspiration by the very large quantity of herbage which grew on these areas following the wet period. While overall yield figures are currently still being computed, herbage yields of up to 3000 kg/ha dry matter from cleared thickets and somewhat less from the cleared inter-thicket areas were recorded.

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THE SIGNIFICANCE OF SHEEP DIET STUDIES IN A SEMI-ARID WOODLAND IN NEW SOUTH WALES

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Abstract

Sheep diet at a plant species level for seven occasions during 1974-76 is presented for a woodland community under four different managements.

The wide variation in grazing preference with treatment and/or time indicates that species manipulation of the herbage may be possible. The fact that sheep, goats, cattle and kangaroos can be expected to have some different preferences gives added managerial possibilities but complicates an already difficult situation.

Such diet studies are an essential prerequisite to the formulation of effective grazing management but require complementary understanding of plant phenology (growth and reproductive phases), productivity and survival under different forms of management.

Introduction

The *Eucalyptus populnea* (poplar box) woodlands cover 60,000 sq. km in N.S.W. and are noted for the shrub encroachment that has taken place since sheep were introduced *ca.* 1870 (Anon. 1969). CSIRO have established an ecosystem study aimed at identifying the crucial factors in management of the vegetation. Potential management has two main components, the reduction in the mass of shrubs in order to promote herbage growth and the manipulation of the herbs to maximise stability and long term animal productivity. Heretofore vegetation management in this area has been restricted to clearing of shrubs and ringbarking trees. Generally speaking the woody vegetation has subsequently reasserted dominance and in some cases ringbarking has appeared to promote shrub encroachment.

Sheep diet studies are used here to indicate the usefulness of this approach in assessing whether a plant community is susceptible to management.

Methods

A 500 ha area of poplar box woodland on "Oakvale", Coolabah, N.S.W. was selected for the wide variety of shrubs it exhibited, arranged in a fairly homogeneous manner.

Two blocks of four 40 ha paddocks were established and the following treatments were applied as from August, 1974:

Treatment 1: Grazed by Merino wethers at 8 ha/sheep. (A moderate stocking rate for this class of country).

Treatment 2: Feral nanny goats at 2 ha/sheep.

Treatment 3: As treatment 2 with additional wethers introduced periodically to consume herbage and enforce a high browsing pressure (goat blitz).

Treatment 4: As treatment 2 with all shrubs and trees <30 cm trunk diameter bulldozed in June-July 1975.

Treatment 5: An exclosure of 100 ha was attached.

Herds of five goats, sheep and cattle, which were habituated to human beings, were introduced to the paddocks at the seven times indicated in tables 1, 2 and 3. The animals were given from 2-7 days to settle into the paddock, as was deemed necessary. The animals were familiar with all the paddocks and were permanently grazed in adjacent paddocks (excepting the cattle) and were, thus, subject to the same array of plants and seasons as other local animals.

The observer moved within the herd, recording the plants eaten, being careful to remain stationary when the observed animal was stationary and move alongside it rather than follow it. In this way any distortion of behaviour due to the presence of the observer was minimised.

At 30 second intervals the plant actually bitten was recorded. The plants "on offer" were then taken to be those in an imaginary 2 m x 1 m quadrat, constructed with the feet of the animal forming the base and centre of one long side. In the type of herbage on this site, where plants are usually discrete, this was not a difficult task on the great majority of occasions. The observed animal was allowed 10 seconds in which to take a bite and if he failed to do so that 30 second period was abandoned. Four animals were observed in a rotation of blocks of 10 records from each animal. Thus the first animal would be recorded for 10 consecutive 30 second periods, followed by the second animal and so on. The information was spoken into a tape recorder and care had to be exercised that the recorder was switched on, that the tape was not exhausted and that a goat had not bitten through a microphone lead!

Initially the animals were recorded for the duration of daylight but as no change in diet with time of day was observed, subsequent records were limited to 100 per animal. Between five and six hours of recording from dawn onwards was normal and included the mid-morning period for rumination.

On completion of the diet records, the observer hand plucked simulated grazed samples from six plants of the species most frequently eaten. This was assumed to be a better measure of diet quality than whole plant samples. Chemical analyses were carried out on these samples.

Each paddock was sampled for herbage at 10 locations previously selected on a 100 m grid which covered the paddock. The eucalypt tree nearest to the grid point was used as the focus for sampling. The ranked quadrat method was used (McIntyre 1952) and four 1 m x 0.5 m quadrats were cut beneath the eucalypt canopy and half way to the next tree in a N, S, E and W direction.

Results

The most commonly occurring plant species and their contribution to the diet of sheep are listed in tables 1-3. On most occasions the figures are averages of 100 recordings for four animals and can be viewed as percentages. "O" is the percentage of times the species was "on offer", "E" is the percentage of times it was eaten and "P" is the "preference rating", i.e. the percentage of times when "on offer" that that species was eaten. Where less than 400 recordings were made the number is indicated.

Attempts to study sheep diet on the goat blitz treatment were abandoned after July 1975 when the sheep grazed desultorily for 1.6 hr on dead spear grass stubble (63%) and litter (34%) but apparently realised they were better off saving their energy for plaintive bleating, which won them a reprieve after four days.

Although large data matrices are wearisome there seems to be no alternative to the publication of such data if we are to build up an understanding of plant/animal relationships and field layer plant dynamics.

Shrubs frequently on offer, which were never acceptable were *Eremophila mitchellii* (budda), *E. sturtii* (turpentine), *E. bowmannii* (silver turkey bush), *Myoporum desertii* (dogwood), *Geijera parviflora* (wilga), *Cassia nemophila* (punty), *C. artemesioides* (silver cassia). Litter from the following species was found highly acceptable on some occasions: *Acacia aneura* (mulga), *A. excelsa* (ironwood), *Apophyllum anomalum* (warrior bush), *Santalum acuminatum* (quandong), *Capparis mitchellii* (wild orange), *Heterodendrum oleifolium* (rosewood), *Eucalyptus intertexta* (red box) and *Ventilago viminalis* (supplejack).

Data from the herbage sampling on the paddocks is not presented here but is an essential requisite to a fuller understanding of the plant/animal relationships.

The nitrogen (N) content of the simulated grazing samples is presented in table 4. Nitrogen content is associated with palatability and diets with a N content less than *ca.* 1.2% usually cause a reduction in the DM intake. Thus inadequate protein nutrition is usually associated with inadequate energy intake.

Fig. 1 depicts the rainfall experienced over the experimental period.

Discussion

Notes on sheep diet

The main purpose of this paper is to present a case for this type of work in our important rangeland pasture types. A classification of plant species order of acceptability to sheep, cattle and goats will be proposed in the Australian Rangeland Journal.

It is clear that to consider sheep diet in terms of grass, forbs, browse etc. is not very useful. Some species within those classifications are acceptable and others are not.

Stipa variabilis (spear grass) was in the flower emergence stage at the first sampling time. The sheep consumed the flowering heads, whilst ignoring the leaves. Three weeks later the heads had all emerged and sheep avoided this species entirely. Sheep were observed to eat green seedlings of this species in December 1975 (table 1) but ignored the dry mature plants (0.58% N in DM). Similar quality, dry spear grass was eaten in July 1975, 63% of the time, when the only alternative was tree litter but the rate of feeding and mass intake was low.

The appearance of large quantities of *Euphorbia drummondii* (caustic weed) and *Boerhavia diffusa* (tar vine) after heavy rains early in 1976 reduced the intake of more perennial herbs such as *Hibiscus sturtii* (hill hibiscus). The growth of these perennial herbs also responded to the rains, however, and this demonstrates how changes in dietary preference can relax grazing pressure on one species for a period, even when that species is actively growing and of high DM quality.

In paddocks cleared of shrubs the rains in early 1976 promoted a greater mass and variety of herbs than on other treatments. This resulted in changes in sheep diet (cf. tables 1 and 3) and a wider variety of species eaten in small quantity, which are represented in the 26% of the diet unaccounted for in table 3. It would seem that most forbs are acceptable when in an immature state, although a notable exception is *Chenopodium cristatum* (desert goosefoot). Once mature, however, some annuals are reduced in acceptability whilst the perennials are subject to great changes in both their growth rate and acceptability. It is interesting to compare the records for March - April 1976 in tables 1 and 2. Due to differential grazing pressure between the two treatments the condition of the various species was quite different. Caustic weed had a lower preference rating on the heavily grazed paddock (table 2) because *H. sturtii*, *Calotis cuneifolia* (purple burr daisy) and *Paspalidium constrictum* (boxgrass) were making fresh growth from stubble, which was attractive to the sheep. On the moderately grazed paddock the fresh growth from these species may have been less easily selected because it was mixed with older material, whereas caustic weed was entirely composed of fresh growth from seeds.

Factors influencing dietary preferences

The above notes on sheep diet are only a sample of detailed discussion that could be made on the different array of species eaten on each occasion. In such a complicated situation, it is sensible to search for some underlying principle to diet selection.

In a field experiment such as this it is impossible to separate the influences of plant species, quality, frequency-of-occurrence and alternatives-on-offer (if any) from those of taste, smell and physical properties of the plant, the physiological condition of the animal (which may alter its nutritional requirements and hence its diet), its instinct and experience.

The data does indicate that high DM quality or high frequency-on-offer or a combination of those two factors, even for a species that has a high preference rating under certain conditions, is no guarantee that that species will be frequently eaten, e.g. *H. krichauffianus*.

Arnold (1964) concluded that an understanding of the criteria for diet selection was critical for range management, but was unable to separate them from the available evidence. To my knowledge the situation has not improved. Westoby's (1974) suggestion that diet selection is driven by a demand to optimize the "nutrient mix" and that a long-delay learning mechanism is involved in the pursuit of this aim, is not satisfactory. From our knowledge of the nutrient content of the plant species eaten here, it seems most unlikely that the dietary changes could be explained in this way.

Conclusions

In view of the difficulty of assessing what influences herbivore diets, we are forced to the empirical approach of recording which plant species herbivores are eating at any one time. In order to use this information to forecast the grazing pressure on the different pasture species, phenological and DM quality information is also required. An ability to forecast grazing pressure *on a plant species basis* is essential if we aspire to manage vegetation, rather than the current concept of property management which is geared to the animals alone.

This aim is complicated by the observed, but insufficiently explained, phenomenon of extreme differences in the botanical composition of the field layer from year to year. Whilst it can often be explained by differences in rainfall patterns, this does not provide a complete explanation. This phenomenon is worthy of further study. It would appear that therophytes, normally thought to act as annuals in this environment (e.g. *Calotis*, *Bassia* spp. are capable of surviving for many years (Cunningham, personal communication). Such plants appear to be capable of surviving short dry periods and resuming growth when soil moisture conditions are favourable. Very often the only viable parts of the plant are below ground and it is not apparent whether the plants which develop come from seed or root stocks after a short period of growth. With the inevitable competition for moisture in a semi-arid environment, survival of short lived perennial herbs through dry periods could have a marked influence on the survival of seedlings resulting from rainfall events. It can be surmised that a flora resulting from a successful germination event might inhibit survival from one or more subsequent events, until the original plants become senile. It is also possible that some species would reach the senile stage earlier than others. Early deaths might be replaced with seedlings or by greater growth from the survivors.

Superimposed on such considerations is the influence of stock grazing the various plant species differentially and the independent influence of different types of stock.

For the flora under consideration Cunningham's forthcoming publication of the phenology of the herbs in the Cobar area will be a foundation for any subsequent success in field layer management. The diet studies presented here for sheep and subsequently for cattle and goats, whilst incomplete, will also be a contribution as are associated studies on field layer plant dynamics, productivity and demography under different managements. More information is required for this vegetation type and could probably be simply acquired by records of herb phenology at marked sites in any paddock that is conveniently visited regularly, provided meteorological and stocking records are available.

Similar information is required for other major Australian rangeland vegetation types that are susceptible to management.

Acknowledgements

Mr. G. R. Sawtell assisted in all aspects of the data collection and interpretation, providing insights which would otherwise have been overlooked.

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Table 1. Frequency on offer (O), per cent eaten (E) and preference rating (P) of the important dietary components of sheep diet on a moderately grazed woodland pasture

	15.9.74†			7.10.74			5.3.75			9.7.75			9.9.75			6.12.75			27.3.76		
	O	E	P	O	E	P	O	E	P	O	E	P	O	E	P	O	E	P	O	E	P
Amphipogon caricinus	36	25	68	27	17	62	21	1	4	5	tr	10	7	1	16	12	5	40	5	-	-
Bassia diacantha	16	tr	2	29	3	12	26	6	25	50	33	66	34	24	70	31	9	29	32	1	4
Boerhavia diffusa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	tr	-	-	29	11	39
Calotis cuneifolia	58	4	14	68	6	9	14	1	7	-	-	-	-	-	-	3	-	-	26	6	22
C. lappulacea	22	12	54	14	4	31	1	tr	-	-	-	-	-	-	-	-	-	-	8	2	21
Chenopodium anidiophyllum	10	1	14	14	1	8	9	-	-	19	9	48	5	3	50	6	1	-	7	tr	-
Eragrostis lacunaria	20	tr	-	26	3	11	29	13	47	12	2	19	3	1	-	4	tr	-	14	tr	-
Euphorbia drummondii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	66	44	67
Goodenia spp.	21	9	25	17	5	29	-	-	-	-	-	-	-	-	-	-	-	-	18	8	46
Hibiscus krichauffianus	3	tr	-	38	tr	tr	54	4	8	37	24	66	36	19	53	20	8	41	27	6	24
H. sturtii	2	-	-	9	-	-	16	3	22	-	-	-	1	-	-	57	37	65	56	2	3
Monacather paradoxa	17	4	37	20	11	52	6	3	56	2	-	-	3	tr	-	3	-	-	3	tr	-
Panicum effusum	13	1	15	29	19	65	46	29	62	-	-	-	-	-	-	-	-	-	7	tr	-
Paspalidium constrictum	6	tr	-	12	tr	-	30	10	33	14	1	-	8	tr	-	28	8	27	27	3	13
Stipa variabilis	51	14	35	67	1	1	54	-	-	59	-	-	53	tr	-	37	2	6*	13	-	-
Thyridiolepis mitchelliana	9	1	-	26	6	23	22	13	42	2	-	-	2	tr	-	9	2	29	10	-	-
Acacia aneura	22	3	13	17	6	36	14	8	58	25	19	77	33	25	75	22	9	43	13	2	13
Dodonaea viscosa	12	-	-	14	-	-	16	3	19	8	4	47	13	10	79	11	3	24	12	2	14
Litter		-			-			-			-			5			7			tr	
Other		26			16			9			8			22			9			13	

† 360 observations

* All the *S. variabilis* eaten was green occurring with a frequency of 6% and a preference rating of 36

Table 2. The important components of sheep diet on a woodland pasture heavily grazed by goats

	4.7.75			11.9.75			4.12.75			10.4.76		
	O	E	P	O	E	P	O	E	P	O	E	P
Amphipogon caricinus	4	-	-	12	3	26	4	2	50	4	2	36
Bassia diacantha	56	43	77	31	25	80	15	11	75	2	1	-
Calotis cuneifolia	2	1	-	-	-	-	-	-	-	42	34	79
Chenopodium anidiophyllum	12	2	21	2	1	33	3	2	50	-	-	-
Eragrostis lacunaria	10	5	50	10	7	70	1	1	-	1	1	-
Euphorbia drummondii	-	-	-	-	-	-	-	-	-	52	9	17
Hibiscus krichauffianus	29	21	78	33	26	80	6	3	58	10	4	46
H. sturtii	-	-	-	-	-	-	2	2	78	41	20	48
Paspalidium constrictum	14	2	14	9	2	26	12	6	53	17	11	61
Stipa variabilis	65	-	-	59	8	13	54	24	45	9	2	28
Grass stubble (green)*	-	-	-	-	-	-	11	7	67	-	-	-
Forb stubble (green)	-	-	-	-	-	-	6	5	81	-	-	-
Acacia aneura	18	14	74	8	2	23	2	tr	-	8	2	23
Dodonaea viscosa	11	4	34	17	12	74	11	7	65	6	5	81
Litter		2			3			24			1	
Other		7			17			12			10	

* Mainly *Eragrostis lacunaria* but not positively identifiable at a distance

Table 3. The important components of sheep diet on a woodland pasture cleared of shrubs

	1.7.75			7.4.76		
	O	E	P	O	E	P
Alternanthera denticulata	-	-	-	21	3	12
Amphipogon caricinus	8	5	71	6	-	-
Bassia diacantha	1	-	-	8	tr	-
Boerhavia diffusa	-	-	-	28	8	28
Calotis cuneifolia	-	-	-	36	4	11
Chenopodium cristatum	-	-	-	26	-	-
Eragrostis lacunaria	4	3	80	26	1	-
Erodium crinitum	-	-	-	35	24	67
Euphorbia drummondii	-	-	-	55	27	49
Goodenia spp.	-	-	-	39	7	23
Panicum effusum	5	4	68	24	tr	-
Paspalidium constrictum	16	10	62	25	-	-
Stipa variabilis	52	4	8	14	-	-
Grass stubble (green)	32	29	89			
Herb stubble (green)	8	7	85			
Acacia aneura	4	2	62	2	-	-
Apophyllum anomalum	9	8	91	-	-	-
Dodonaea viscosa	25	14	56	10	-	-
Other		14			26	

Table 4. Nitrogen (N) content of DM of simulated grazed samples of important components of sheep diet. Figures in brackets apply to table 2 where they differ from samples from table 1 by more than ± 0.1%. Figures in italics indicate a whole plant sample instead of a simulation grazing.

	Oct.74 %N	Mar.75 %N	July 75 %N	Sept.75 %N	Dec.75 %N
Amphipogon caricinus	1.36	0.46	*0.84* (0.31)	0.98	-
Bassia diacantha	2.97	3.15	2.33 (1.98)	1.97	2.90
Boerhavia diffusa	-	-	-	-	2.83
Calotis cuneifolia	-	-	-	-	-
C. lappulacea	1.36	-	-	-	-
Chenopodium anidiophyllum	3.10	3.10	2.52 (1.40)	-	3.63
C. cristatum	-	1.47	-	-	-
Eragrostis lacunaria	*1.09*	1.16	0.95 (1.15)	- (1.12)	-
Goodenia spp.	2.44	-	-	-	-
Hibiscus krichauffianus	1.87	2.84	2.22	1.53 (1.32)	3.04
H. sturtii	2.18	-	2.36	-	2.77
Monacather paradoxa	1.48	-	-	- (0.63)	-
Panicum effusum	2.14	1.48 (dry)	0.87	-	2.38
Paspalidium constrictum	*1.10*	1.72	1.57	*1.34* (1.22)	2.33
Stipa variabilis	1.36	0.60 (dry)	0.92 (0.75)	0.66 (0.84)	0.58
Acacia aneura	-	2.17	1.82	1.99	2.15
Apophyllum anomalum	-	2.31	1.92	2.45	-
Exocarpus aphylla	-	0.80	0.92	1.09	2.56
Dodonaea viscosa	-	1.70	1.72	1.95	2.37
Myoporum desertii	-	1.60	1.92	1.70	2.27
Capparis mitchellii (litter)	-	-	-	2.54	3.48
Cassia seeds	-	-	-	3.32	3.30
S. variabilis seeds	-	-	-	0.40 (1.13)	-
Eucalyptus intertexta (litter)	-	-	-	-	1.14

STUDIES ON A FREE RANGING CATTLE HERD IN THE PILBARA REGION OF WESTERN AUSTRALIA

Changes in Breeding Herd Structure and the Effect of Vaccination with Botulinum C+D Vaccine over a Four Year Period

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Introduction

Records were kept of the free ranging cattle herd on Prairie Downs station. Prairie Downs is located approximately 70 km South of the town of Newman in the East Pilbara region of W.A. The area has an average annual rainfall of approximately 225 mm falling predominantly during the summer months.

The station is located across the divide between the Ashburton and Fortescue River basins and includes areas of rugged rocky hill terrain with steep sided creeks. Hill areas carry sparse annual grass cover (*Aristida contorta*) with scattered small shrubs (*Solanuj lasiophyllum, Ptilotus obovatus* and *Cassia spp*), under a stunted (*Acacia spp*) overstorey. Rugged hills nearer Newman often carry Spinifex (*Triodia spp*) and Bloodwood (*Eucalyptus spp*).

Where runoff is slower, alluvial flats, often with gilgiaed soils have developed. These carry a good cover of native annual and perennial grasses, (*Chloris spp, Panicum spp, Astrebla spp* and *Aristida contorta*). Occasional pockets of chenpod pastures can still be found carrying *Maireana pyramidata, Rhagodia spp* and *Atriplex paludosa*. These are generally isolated and often inaccessible except in high rainfall years.

When the investigation commenced in 1973 there were only ten waters, consequently areas around these mills are severely degraded. The halo effect of grazing often extending up to 2 km from the mill. The cattle were run on an open range principle and bulls were running with the herd continuously, no weaning was practised. One main muster was carried out each year in August-September. Other smaller musters to draft off sale cattle are carried out sporadically during the year. Most of the brandings were carried out at the main muster when an attempt to yard all cattle was made. This was the only muster attended by Departmental Staff.

Since 1973 three new windmills have been erected and one new holding paddock built. Unfortunately the extra mills did not alleviate stocking pressures on existing mills because of a dramatic increase in cattle numbers from 1973 - 1976. The holding paddock made cattle handling easier and contributed to the smooth running of subsequent musters.

Methods

Mustering

Two main yards were used during the muster, one at the homestead on the western end of the run and one on the eastern end of the run. The station was mustered in defined areas and the cattle from each area kept separate and returned to the same area. Waters were shut off the morning before an area was to be mustered and most cattle were picked up at the mills.

On the eastern end of the run, by far the most rugged, a light aircraft was used in conjunction with short wheel base landrovers and men on horseback. All were in two way radio contact. Cattle were mobbed up by the aircraft and landrovers and then driven back to the yards by the horsemen. Often drives as long as twenty kilometers were completed in one day.

On the western end of the run the light aircraft was not used and the less rugged terrain mustered using landrovers and horses.

The mustering techniques appeared to be satisfactory as long as there was no surface water and cattle were watering every day. Only in 1973 did the muster appear to be unsatisfactory.

Handling

At both yards in 1973 all animals were put through a bale and every animal tagged with a coloured and numbered, Lone Star brand, eartag. All calves branded each year were tagged with a specific colour and number range.

In subsequent years the animals were recorded, if present, by noting the colour and number of each animal's eartag as it passed through the bale. Other details, including condition, lactation status and stage of pregnancy were also recorded in some years, these will be the subject of future papers.

All even numbered cattle, including even numbered calves, present at each muster were vaccinated sub cutaneously with five mls of bivalent C+D Botulinum vaccine. An agrimatic automatic vaccinating gun was used. All odd numbered animals were left unvaccinated. By comparing the numbers of even and odd numbered cattle it was possible to examine the effect of vaccinating for prevention of Botulism.

Results

Herd Structure

Cattle mustered each year are shown in Table 1. These are divided into male and female for clarity. Some idea of the 'wastage' of animals can be seen through the years, however figures for the animals present do not give a true indication of actual wastage since many animals miss one year and then turn up in later years. The reduction of numbers from left to right across the table represents a combination of deaths, sales and mustering short fall.

The age structure of the breeder herd can be determined from the mustering records and shows a change towards a much younger herd during the course of the investigation (see Table 2). In this case and in Table 3 the vaccinated and non vaccinated animals have been lumped to form the one figure, since the age structure and survival patterns were similar for both vaccinated and non vaccinated animals.

As the age structure has changed during the course of the investigation so too have the survival patterns for groups of animals born in the same year. Table 3 highlights these changes but care must be taken when interpreting the changes from 1975 - 1976 as there has been no correction for cattle still alive but that missed the 1976 muster.

The male animals were not included in structure or age class survival diagrams as there were many sales that were not recorded and survival patterns would tend to give a false impression. Recorded sales for the four year period are shown in Table 5. This figure is lower than the actual numbers sold.

Vaccination with botulinum bivaleut C+D vaccine

Tables 4 and 5 show a breakdown of the effect of vaccination with the above vaccine into survival, sales, missing for the last one, two or three consecutive years. Using Chi square analyses, with the null hypothesis that vaccination would have no effect, then there was no significant effect from vaccinating in any way of the groups. The results showed non significance for both female (Table 4) and male (Table 5) animals.

Further breakdown of the survival data into the various age classes (Table 6 and 7) again revealed no significant difference in survival rates for male (Table 6) or female (Table 7) animals as a result of vaccination.

1972, the year prior to the commencement of the investigation, was very dry and feed very scarce. Heavy rains throughout 1973 led to abundant feed and plenty of surface water in that year. 1974 was a more 'average' year and abundant grass and herbage was available until late in the year. 1975 was another average year and fodder was still plentiful although animal condition suggested the feed quality was not as good as in the previous two years. 1976 was a drier year with feed available probably a limiting factor, particularly in the immediate vicinity of watering points.

Table 1 Showing wastage of animal numbers from figures present at each muster.

N.B. Sales have not been included as wastage but is included as present for the year in which the animal was sold

SEX	YEAR FIRST PRESENT	PRESENT 1973	PRESENT 1974	PRESENT 1975	PRESENT 1976
Male	1973	169	156	132	37
	1974		190	157	91
	1975			250	186
	1976				220
	Sub Total	169	346	539	534
Female	1973	476	395	370	307
	1974		251	216	181
	1975			267	178
	1976				275
	Sub Total	476	646	853	941
	TOTAL	645	992	1392	1475

TABLE 2. SHOWING THE AGE STRUCTURE OF THE BREEDERS IN EACH OF THE FOUR YEARS

N.B. Areas above solid black lines represent animals present but not mustered in the previous year.

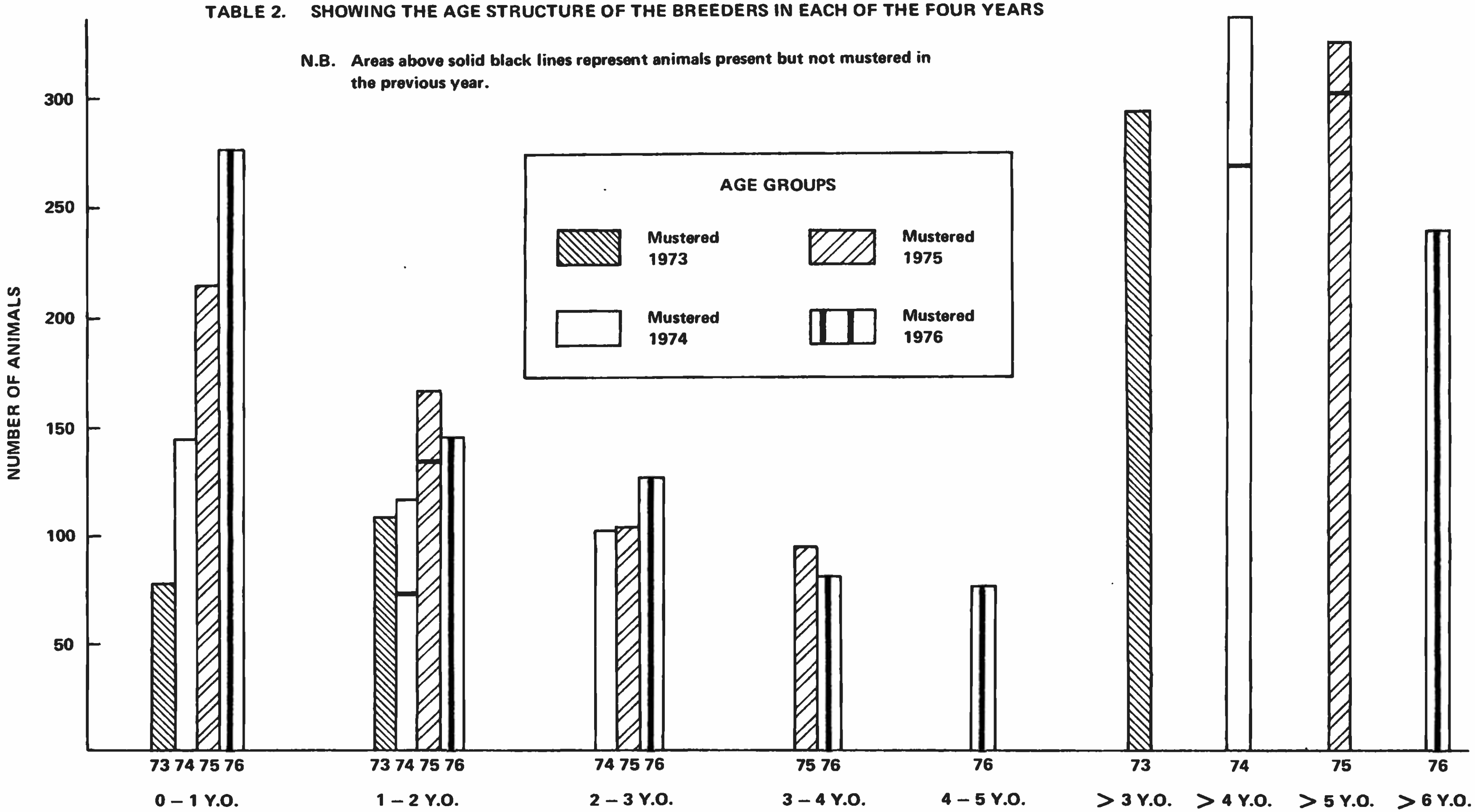

TABLE 3. SHOWING THE SURVIVAL OF FEMALE ANIMAL GROUPS THROUGH TIME

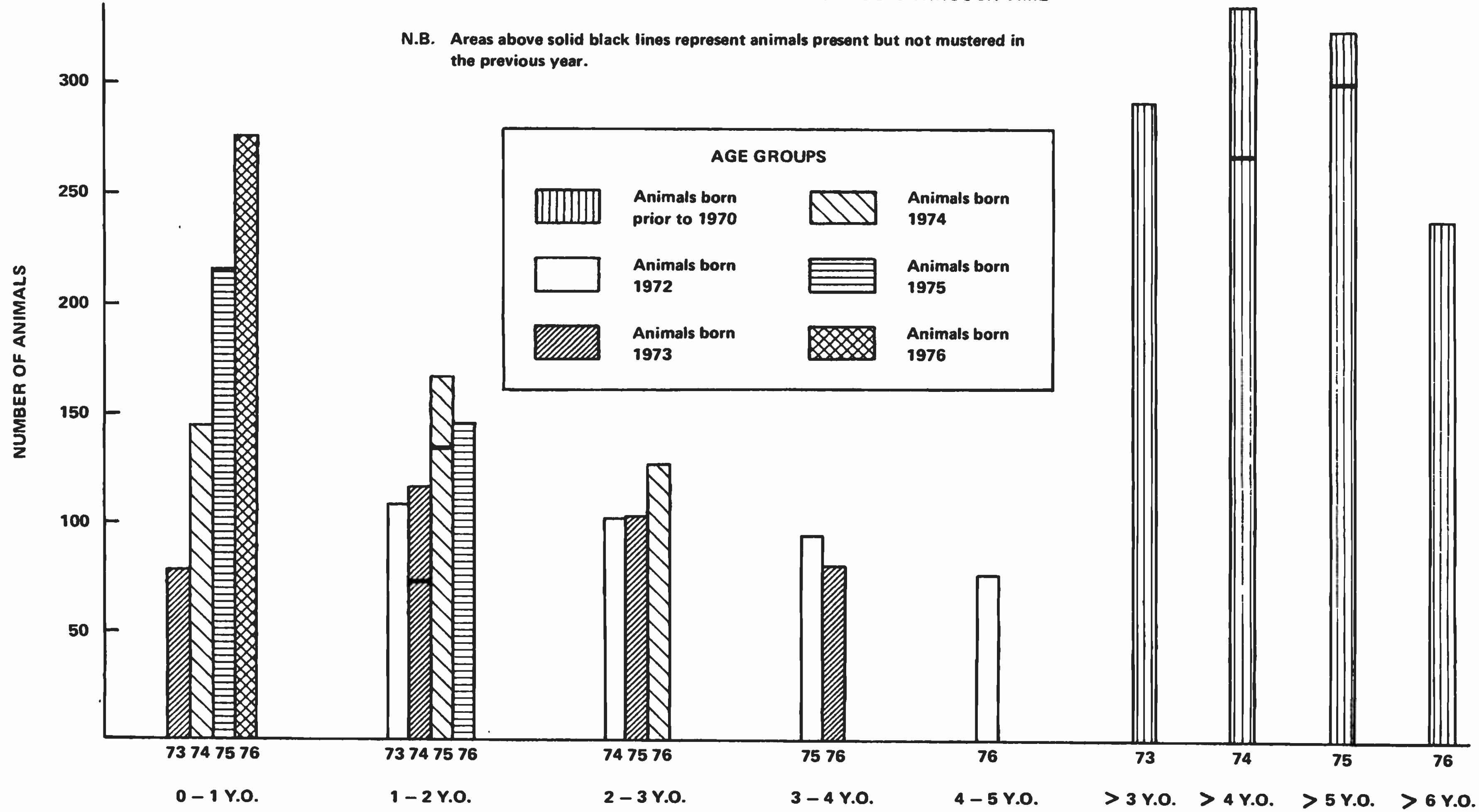

Table 4. Showing survival, sales and annual wastage of numbers of female cattle born in the various years.

AGE CLASS (Year Born)	SURVIVAL		SALES		MISSING LAST YEAR		MISSING LAST 2 YEARS		MISSING LAST 3 YEARS		TOTAL
	Vac.	N.Vac.	Vac.	N.Vac.	Vac.	N.Vac.	Vac.	N.Vac.	Vac.	N.Vac	
1970 or earlier	404	351	1	1	44	40	14	20	7	17	899
1972	128	119	-	-	10	7	1	7	3	3	278
1973	124	118	1	4	13	7	3	10	2	2	284
1974	132	126	1	1	23	14	1	8	-	-	306
1975	73	71	-	-	34	35	-	-	-	-	213
TOTAL	861	785	3	6	124	103	19	45	12	22	1980
X^2	2.1824 N.S.		0.9000 N.S.		2.3617 N.S.		7.3862 N.S.		2.0833 N.S.		

Table 5. Showing survival, sales and annual wastage of numbers of male cattle born in the various years.

AGE CLASS (Year Born)	SURVIVAL		SALES		MISSING LAST YEAR		MISSING LAST 2 YEARS		MISSING LAST 3 YEARS		TOTAL
	Vac.	N.Vac.	Vac.	N.Vac.	Vac.	N.Vac.	Vac.	N.Vac.	Vac.	N.Vac.	
1972 or earlier	57	63	7	13	16	15	11	5	12	14	213
1973	98	124	17	18	31	29	10	7	2	0	336
1974	92	85	4	4	14	25	8	6	-	-	238
1975	91	91	2	0	30	30	-	-	-	-	244
TOTAL	338	363	30	35	91	99	29	18	14	14	1034
X^2	1.8109 N.S.		1.9143 N.S.		1.6007 N.S.		1.5326 N.S.		1.0769 N.S.		

Table 6. Showing the numbers of male animals surviving 12 months after vaccination or non vaccination at various ages.

AGE	VAC.	N. VAC.
5 yo + >	5	10
4 yo + >	16	16
3 yo + >	36	30
2-3 yo	10	12
1-2 yo	67	74
0-1 yo	204	214
TOTAL	338	356

$X^2 = 1.4903$ N.S.

Table 7. Showing the number of female animals surviving 12 months after vaccination or non vaccination at various ages.

AGE	VAC.	N. VAC.
6 yo + >	9	7
5 yo + >	109	90
4 yo + >	147	125
3 yo + >	139	129
3-4 yo	35	33
2-3 yo	79	70
1-2 yo	163	160
0-1 yo	180	171
TOTAL	861	785

$X^2 = 2.5388$ N.S.

Rainfall records and comment on Pasture available

TABLE 8 ANNUAL RAINFALL (mm)

1972	1973	1974	1975	1976
95.4	448.4	216.8	284.0	227.0

Discussion

Herd Structure

The increase in cattle numbers from 645 - 1475 in the four years (1973 - 1976) was due to very high calving rates in 1974, 1975 and 1976 (67%, 93% and 91% respectively). Plentiful surface water in 1973 meant cattle were scattered and difficult to muster and the high mustering short fall increases the difference between 1973 and 1976 numbers. Sales were low for the four year period due to initial attempts to build up the herd numbers and later due to low cattle prices.

The high calving rates mentioned above are almost certainly due to the very high rainfall year in 1974 and subsequent 'average' seasons that have provided adequate forage to maintain calving rates at high levels.

There has been no active culling of the breeding herd and the influx of large numbers of young animals has effectively changed the age structure of the herd. In 1973 38% of the females were less than three years of age while in 1976 this had increased to 58%.

Survival patterns in groups of females of the same age were examined in an attempt to pin point areas of highest loss. From Table 3 these appear to be at weaning, during the first calving season and as old cows. These areas of loss do not necessarily all occur as high components of loss in every year. For example weaning losses were high in 1975 - 1976 but were not outstanding in other years. Losses at first calving were high in 1974 - 1975 and 1975 - 1976 and old cows only in 1975 - 1976.

Botulinum vaccination

Contrary to the situation in the wetter tropical areas of Western Australia, The Northern Territory and Queensland, botulism poisoning does not appear to be a significant cause of cattle deaths in the semi arid Pilbara region of Western Australia. During the four years of the investigation there was neither significant increase in survival or sales, nor significant decrease in cattle missing for the last one, two or three years as a result of vaccination. Both male and female animals showed non significant results.

It should be emphasised that there were no very dry years during the investigation and it may be that if cattle were subjected to severe nutritional stress they may be more susceptible to botulism.

Management Implications

Animal numbers can build up rapidly during good seasons and advantage should be taken of these build ups to increase sales in the form of cull females. It should be possible to upgrade the breeding herd by culling young females with undesirable traits and by culling old cows.

Animals should receive special care during weaning and first calving phases, perhaps paddocks should be erected on better pasture types for weaning. First calvers should be watched closely in an attempt to reduce losses.

Old cows (greater than 6 - 8 years old) should be sold as culls to reduce losses from cow death.

It is particularly important to have a fixed selling and culling programme and to meet the market prices for all classes of cattle rather than 'hang' on and thus overstock country that will provide future drought reserves. Some evidence of over-stocking can be seen in the 1975 - 1976 losses when overgrazing around mills was becoming particularly noticeable.

Vaccinating against Botulism would not appear warranted in the seasons experienced during the course of the investigation.

Conclusions

During a run of 'average' and 'above average' seasons reproductive rates are very high and herd numbers build up rapidly.

Weaners and first calvers require special management to avoid high losses, weaners requiring better pasture areas and first calvers more frequent observation.

Cows greater than 6 to 8 years old should be culled.

During periods of rapid herd build up young breeders should be culled to upgrade the herd.

Vaccination against botulism is not necessary in 'normal' seasons.

RANGELAND GRAZING CAPACITY - AN OVERVIEW

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Introduction

Control of animal numbers is the most importent management tool available for use on extensive pastoral lands. Other complementary tools include the control of animal distribution through the location of waters, salt or fences, and control of the season of use. Use of fire, reseeding, cultivation and supplementary feeding might also be considered, though are less important in the pastoral areas.

Control of animal numbers, including the ratio of age classes and animal species within the herd, has a direct influence on the growth and development of the pasture and on the productivity of each animal within the herd. As each animal grazes, it reduces the quantity and quality of the available forage. It influences the diet of other animals in the herd and it influences the growth or development of the pasture. Grazing studies have shown that excessive stocking rates result in pasture deterioration and a fall in animal production. However low stocking rates result in inefficient use of pasture and lower productivity per hectare. There is a need to reliably assess the grazing capacity of the pasture and to set stocking rates accordingly.

Grazing capacity has been defined as the maximum number of animals which can be grazed on a given area of land without damage to the vegetation or related land resources. It is often recognised as a year round, whole property figure and incorporates the concept of an area of pastoral land being able to carry the same number of animals year after year. In practice, the ability or capacity of a given area of pastoral land to be grazed varies considerably from year to year with seasonal conditions, with the location of stock waters or fences, and with animal management. The production of perennial forage can be 2 to 3 times as much in one year as in another and annual forage production can be 10 times as much in one year as in another. The location of stock waters, and whether animals are grazed year round or seasonally, affects the grazing capacity. In effect, the grazing capacity varies from year to year and even from season to season. While for administrative purposes, a year in year out 'average' grazing capacity is desirable, the manager of the pastoral property must take the variation from year to year into account and adjust his animal numbers accordingly.

Stocking rate has been defined as the actual number of animals using a given area of land. It is an inventory figure of the number of cattle, sheep, goats, kangaroo, deer or wild horses using the area of pastoral land and hence is not usually subject to the same debate as is grazing capacity. It is varied by the land manager according to the seasonal conditions, the market, the economic situation or his own management goals.

The carrying capacity results from the productivity levels of all the land resources. These may be recreational, water, forest, clean air or wildlife resources. It should not be confused with the grazing capacity. Hence, as many carrying capacities can be defined as there are management objectives and the carrying capacity is defined in terms of the products. It expresses the greatest return of combined products without damage to the land resources.

The use of grazing capacity in management of pastoral lands has been subject to dispute and lengthy debate by land administrators and teachers. Grazing capacity is extensively used to value pastoral land for rental or sale. However some land managers and teachers, particularly within parts of America, dispute its use as an aid to pastoral land management. The criticism has come from closer settled pastoral areas which have the capability and the infrastructure to move animals at any time of the year. In the extensive pastoral areas of Australia where animals can only be mustered once or twice a year, and pastures cannot be assessed in the same detail as in closer settled areas, assessment of grazing capacity is an important aid to management of the pastoral property.

Assessment of Grazing Capacity

Determination of grazing capacity is not an easy task as it incorporates many production variables. The assessment techniques can provide only an estimate of grazing capacity and are inherently subject to bias. General guidelines cannot cover all possible situations and the final evaluation and interpretation is the responsibility of the assessor. The estimate is, however, still the proper place for management to begin.

Methods to assess grazing capacity fall into 3 general categories:

1. Those based on actual use records, regional statistics or personal experience of an area, all of which imply a knowledge of the area or a similar area over a period of time.

2. Those based on the forage available for use or the utilization of the available forage and which provide a grazing capacity for the particular grazing season.

3. Those based on a rating of the natural resource characteristics of the area being assessed and which may be related to a standard area.

In practice, the experienced assessor will most likely use at least 2 of the above methods either mentally or in a formal assessment to arrive at a grazing capacity. For clarity of presentation the assessment methods are best discussed individually according to their technique and background.

(1) Assessment by the Use of Records

(a) Actual Use Records -

Stocking records from a selection of 'best properties' or stocking rate experiments can provide the best guide to grazing capacity. However they are only of value when (a) they are accurate; (b) they are in sufficient detail to indicate the area and days grazed each year; and (c) the land was being properly grazed. These 3 requirements unfortunately eliminate many of our available actual use records.

Rangeland managers in the U.S.A. have been provided with data from a series of grazing intensity experiments established in each of the major range types during the 1930s. With grazing at high, medium and low levels of pasture utilization, these areas have provided basic information on animal production and pasture response. Subsequent work has added to these results. For example, rangeland research workers advise that maximum returns are achieved from grazing blue gramma range of the American prairie to a level which leaves 300 kg./hectare of herbage for soil protection and the next season's growth. Grazing studies have provided similar information about the dry veldt in South Africa.

Many country people abhor detailed records, statistics or anything to do with paperwork but there are some who have kept detailed and accurate records of stock and pastures in tabular form or in diaries. They provide a good basis for grazing capacity assessment when analysed together with a study of the current condition and trend of the pastures on the property.

The use of records has been extended to what has been called the 'best property analysis'. This is a detailed analysis of records of property operations and performance from a group of leading properties in each main resource area. The aim of the analysis is to determine the maximum potential or the production capacity for each pasture type under the best management system. As only the maximum potential is required, the sample properties in the survey need only be the leading properties of an area. The records must be collected accurately, in detail, and be adequate to separate the effect of animals moving from pasture to pasture. The data sheets for collection of records, while looking formidable at first sight, are relatively easy to follow. The procedure is being used by the Department of Agricultural Technical Services in South Africa and by the university extension services in the U.S.A.

(b) Regional Statistics -

Annual returns of animal numbers are the stocking rates for the area and may bear little relationship to the grazing capacity. Their accuracy, especially from extensive pastoral areas, is often in doubt and because they are a whole property figure, they relate to a variety of pasture types and even to non-grazed portions of the property. They are of little use in assessing the grazing capacity of a property or pasture.

(c) Personal Experience -

Most guides to grazing capacity assessment end with the advice to use local experience to determine if the assessment is reasonable or even to adjust a formal assessment. Such advice is given with good reason for, even with the considerable advances of science, management of pastoral lands is still an art, dependent very much on experience. The ability to co-ordinate the many variables influencing grazing capacity, e.g. climate, soil type, forage quality, animal preference, grazing distance, is still largely unsolved by science and cannot be expressed simply by mathematical formulae alone.

The efforts of individuals assessing the same area independently can lead to varying results. However, the efforts of a group working together lead to a more reliable result. Individuals within the group will use an overlapping set of variables including seasonal variation, the productivity of the pasture, the animal requirements, the effect of waters, fences, management, etc. As a group they can influence each other to form a balanced result. The group must be broadly based to avoid bias.

(2) Assessment based on Forage Availability

Assessment of grazing capacity based on the available forage is well adapted to those pastoral lands with short and variable seasonal growth periods. Estimates or measurements of the available forage are made within the pasture and are either compared to a similar area of known grazing capacity or simply divided by the pasture requirements of the animal per day, month or year. Some experience is required by the assessor to estimate the mass of forage within the pasture and he must also have a knowledge of the forage requirements and pasture preferences of the animal. The method is flexible and does relate the forage produced by the pasture directly to the animal requirements.

The use of the forage supply in assessment of grazing capacity is widely used, e.g. by the U.S. land management agencies and extension services, in Africa by the British Overseas Development Administration, Land Resources Division, and in Australia by the Rangeland Management Branch of the Western Australian Department of Agriculture.

The methods fall into 3 groups: (a) forage mass available; (b) a forage acre factor; and (c) a forage utilization method. The assessments of forage supply might also be by visual assessments, by cut samples or by double sampling techniques involving some cut samples and some visual assessments.

(a) Forage Available/Animal Requirement -

The method is based on an assessment of the mass of forage available and the requirements of the animals to be grazed. It should take into account the preference of the animal for particular species at different times of the year and the differences between species, size, age and reproductive status of animals.

A good land resource map is essential before starting the forage survey. If not available it should be prepared and should include the boundaries of the pasture types on the property, the waters, fences and other structural improvements. It should also indicate inaccessible, special use, or problem areas.

In each pasture type the total mass of forage and the percentage composition by weight of the major forage species are assessed. The forage available to the animal can then be calculated by either using a forage utilization factor, e.g. the residual of 300-400 kg./ha. on the 'blue gramma range' mentioned earlier, or by applying a proper use factor. In practice, from experience the proper use factor is normally 50%. The species preference of the animal and the seasonal availability of species is also taken into account when calculating total forage available.

From a knowledge of the animal intake requirements, the grazing capacity in terms of animals per unit area per unit time can then be calculated. In practice, the method is subject to the problems of sampling pastoral areas, of knowing animal preferences, and to the variability in animal intake.

(b) Forage Acre Factor -

Essentially the method is similar to the available forage method in that the forage species are listed for each pasture unit together with the composition of the pasture and the total density of the pasture. The composition of each species is multiplied by its safe use factor and by the pasture unit density to arrive at a forage index which is the forage acre factor. This factor expresses the area covered with available vegetation which can be eaten in entirety by animals without damage to the pasture. The forage acre factor is then multiplied by the total area of the pasture type and the grazing capacity assessed from a standard for the pasture type. The method is difficult to follow and its accuracy is questionable. Forage production per unit of plant density varies tremendously between species and the reproductibility of the method is doubtful.

(c) Forage Utilization -

Forage utilization by a known number of animals is used extensively on seasonal pastoral lands in the U.S.A. to determine grazing capacity. The procedure requires a knowledge of the actual amount of use in terms of animal days or animal months and of the pasture available for use at the start of the grazing period. The known use when related to the degree of utilization and the amount of forage remaining can be used to determine the remaining grazing capacity. The method is dependent on knowledge of proper use for the pasture and of an adequate sample of utilization. The main difficulty is how one estimates something which has disappeared or has been eaten. Use has been made of cages and paired plots to overcome this difficulty. The method is a good check on the effect of the current stocking rate. If it is used with estimates of forage availability early in the season, it would provide a good estimate of grazing capacity, especially if utilized over several seasons.

(3) Assessment by Rating of Natural Resource Characteristics

The methods under this category assign a factor or a rating to those characteristics of the pasture unit which determine its productivity. They utilize the factor for comparison with a standard pasture unit and calculation of a grazing capacity. The characteristics rated in the methods studied included the soils, topography, pasture condition, presence or absence of trees or hills and the climate of the pasture unit.

The method developed by the Soil Conservation Service of New South Wales for use in central Australia and in the western division of N.S.W. is in this category. A very similar technique is used by the Division of Land Utilization in Natal, South Africa. The method unfortunately suffers from the lack of objective data on which to rank the characteristics of the pasture unit. It also suffers from the lack of a reliable base grazing capacity for the standard. Error in the base grazing capacity can create a greater error than the ranking factor given to characteristics of the unit. This is unfortunate for the method is easy to use as an administrative tool for assessment of pastoral properties.

Conclusion

There is no entirely satisfactory method to assess grazing capacity of pastoral areas. Until actual use records are available for several years, managers and land administrators must continue to rely heavily on experience backed by a number of imperfect procedures.

The collection of actual use records should be a goal for those involved in management of pastoral lands. These must include the number, age and species of animals, the pasture composition and yield and the degree of utilization of the pasture, for a range of major pasture units.

With the limiting manpower resources in pastoral areas it will not be possible to gain use records for all pasture units. A better understanding of the composition and amount of animal intake and of safe levels of pasture utilization would assist assessments of grazing capacity on areas for which records are not available.

A reliable method of grazing capacity assessment would directly assist the property manager to adjust herd numbers to maintain an adequate level of animal production under safe levels of pasture utilization. This would maintain the productive potential of his pasture resources in spite of varying seasons. It would also provide a better base for land administrators using grazing capacity to assign land values and rental.

Summary

The importance of grazing capacity assessment in pastoral areas is discussed in this paper. Methods of assessing grazing capacity based on (a) actual use data; (b) forage availability; and (c) a rating of natural resource characteristics are described and briefly discussed. The paper outlines base studies and data required to improve the known methods.

THE ROLE OF LIVESTOCK IN RANGE MANAGEMENT

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Introduction

Historically, livestock have been the main method of converting rangeland production into financial returns. It is possible that livestock will continue in this role, for the major portion of Australia's settled rangelands. However, while fulfilling this role livestock should also be considered as useful range management tools.

Traditionally, increased output from livestock has tended to rely rather heavily on genetic improvement. While gains can be made in this manner, reflection of the achievement will not be great unless nutrition is adequate in the short-term and stable in the longer-term. Management of our range sites has tended to look at the short-term end of the scale, with the longer-term result being lowered range condition and lower livestock production.

Background

The basis of utilizing Australias rangelands, will remain livestock. We should not only consider the effects that livestock have on our rangelands but also, how these can be used to our advantage.

Most of us recognise that some degree of degeneration has followed the establishment of grazing industries on our rangelands. The degree of degeneration varies with range site and time. It is continuing on some sites, stable on others. Also probable is that some alteration to the pristine state is desirable in maximising livestock productivity. However, the range condition that maximises livestock production over time, while maintaining a stable range site, has not been realised on most sites. Many reasons for this have been postulated. The most likely is that managers of our rangelands have managed their stock on a seasonal basis rather than their rangelands. Using this approach, short-term animal productivity has been maximised while long-term condition may have been adversely affected.

A concept that has been considered basic to the utilization of range sites is that a particular site is good sheep country and not good cattle country, or vice versa. This philosophy has led to the depasturing of predominately single animal species on range sites without consideration of what may be the long-term effect. Production has been measured as the amount of wool produced, lambs marked or cattle sold. In short-term economic analysis these units of produce may have given the best return.

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However, a more suitable measure might be units of animal protein turned-off as a whole, its components being made up of wool, cattle or sheep. Such an approach, is not as affected by short-term price fluctuations, but is more conducive to longer-term management of rangelands.

Philosophy

A look at almost any range site will reveal a collection of plants that differ in their ability to be harvested, their response to harvest, and their requirements for growth. Range managers will tell you which they consider best in maximising livestock production. In broad terms we know that sheep prefer and do best on short green herbages and grasses and that cattle prefer longer grasses. The reasons are easily confirmed by animal physiology and observation. Rarely does a range site contain plants suitable to only sheep or cattle, yet they are usually managed in this manner.

A common sign of degraded range sites is "invasion" by scrub. Even with scrub being present and increasing on some sites, we do not attempt to depasture an animal that may utilise some scrub species. We persist with sheep or cattle neither of which prefer to utilise much browse. The introduction of a browsing animal to range sites that have a scrub component can lead to more balanced utilization. The most obvious animal to introduce, because of its relative abundance, is the goat. Like sheep and cattle, they do not rely solely on one component of the range site nor do they consume all plants available in that component. However, at present almost all scrub species are not consumed by either sheep or cattle unless pressed by drought or like management. In seasons of high rainfall most scrub species are able to grow without the threat of harvest by sheep or cattle. They are therefore able to become firmly established during the good seasons and thus to provide a threat to the growth of other range components during lower rainfall seasons.

Application

If rangeland conditions deteriorate sufficiently, it is sometimes necessary to introduce somewhat drastic procedures to restore productivity. Techniques such as ridge furrowing, pitting, water-ponding and clearing, all with or without re-seeding, may be employed. While successful in re-vegetating suitable areas, and sometimes giving good short-term economic returns, future management of treated areas requires consideration. If treated areas are to remain productive and not return to a state where similar treatment is again necessary, then sound management is necessary.

Recognising the plants to be encouraged in treated range sites will give clues to the future management required. The ability of various livestock species to utilize range components can suggest the species of livestock to be depastured. Obviously their rate of stocking and the time of year will have to be considered.

Although many of the factors needed to be known about the growth of individual plant species are yet to be studied, a simple stocking plan can be drawn. Stocking rate and length of deferment before grazing will be suggested from local experience, rainfall events and like factors. The type of stock depastured will be determined by the plants existing in the treated area and the plants to be encouraged. If scrub is likely to be a problem then goats may be considered, while light stocking rates of cattle will encourage perennial grass and shrub growth. Stocking with sheep to utilize herbage growth over winter may be considered.

Until such time as sufficient information is available from floristic studies and defoliation/carbohydrate reserve studies, broad management plans can be evolved. Exploitation of the diet preferences of livestock can be seen as a means of obtaining a balanced level of defoliation, while deferment or rests during critical growth periods of plants, may also be considered. Even without the aid of floristic studies, the growth of preferred species at a particular time of the year following a particular rainfall event is generally known. Under a given set of conditions, a prediction of the value of deferrment on a particular species can be made. If the species chosen is a preferred species and is perennial, then deferment during its growth to seed set stage would allow the plant to maximise root and aerial growth and carbohydrate storage, while allowing the production of a new lot of seed. A vigorous plant, capable of withstanding subsequent grazing and a replenished seed store results from such treatment.

Conclusion

Many aspects of rangelands require study to fully develop the knowledge needed to design the most desirable management for a range site. However, recognition of the preferred diet of livestock and consideration of plant requirements will allow us to develop range management programmes capable of at least holding many range sites in their current condition.

In this sense, livestock can be viewed as being another range management tool as well as being the principal means of harvesting rangelands. In order that the full potential of livestock as range management tools be realised, research on animal dièts and plant growth rythms is needed. This work should be done on a selected range site under a best bet management system.

Such an approach allows study of individual livestock and plant species or combinations of these while allowing assessment of overall effect. A site developed to this standard would allow for the development of range assessment techniques suitable for use by researchers and managers alike.

Livestock will remain the main means of harvesting our rangelands. They should also be recognised as an important tool available for use in rangeland management. Combined with treatments designed to assist the growth of desirable plant species, livestock can be manipulated in multi-animal grazing systems designed to ensure the long-term stability of our rangelands.