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THE EFFECT OF GRAZING AND BURNING ON A MOUNTAIN GRASSLAND, SNOWY MOUNTAINS, NEW SOUTH WALES

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The effect of re-introducing summer grazing and control burning on to a sod-tussock grassland in the Snowy Mountains has been examined.

Grazing caused continued loss of cover on all grassland studied except the densest; even here deterioration in quality occurred. Regeneration to prefire condition occurred within five seasons of a controlled burn in the absence of grazing, but had not occurred after six seasons when grazed.

Management implications of the findings are discussed.

THE subject of grazing of the snowgrass (*Poa spp.*) grasslands of the alpine tract and the air-drainage valleys of the Snowy Mountains has long been contentious. Costin (1954, 1957, 1958) and Costin *et al.* (1959, 1960) have pointed to the potential disadvantages of grazing. Newman (1954) and Taylor (1956) have drawn attention to the associated erosion problems.

Grazing of the more accessible areas had commenced by the 1830's (Newman, 1954) and was regular at the highest elevations for at least a century.

Many areas were excluded from grazing in the period 1950 to 1957, and finally in 1958 all areas above 1,475m within the Kosciusko National Park were excluded from grazing. A re-assessment in 1961–1962 determined that restricted grassland and woodland areas of general elevation 1,410m to 1,510m should be re-introduced to transhumant grazing under snow lease conditions involving the annual movement of stock to and from the mountains each spring and autumn.

This presented an opportunity to trace the vegetation and cover patterns under the influence of transhumant summer grazing. However, within 3 years, fire—both as a management tool and as a hazard (wildfire)—had re-appeared.

The increased availability of aerial photo coverage of the mountains made possible the assessment of general trends in vegetative cover over a 26-year period from 1944 to 1970.

This study records examination of trends in vegetal cover of a mountain grassland following the re-introduction of transhumant grazing and periodic burning.

STUDY AREAS

The study areas were Snow Lease Blocks E10, H10 and B5. After regular transhumant grazing at uncontrolled levels for a century until 1943, grazing limitations were imposed until 1958 (table 1). Grazing was then prohibited.

Block B5 was not grazed again except during the period April to August, 1965 (legally) and during spring, 1968 (illegally). Blocks E10 and H10 were reopened to limited transhumant summer grazing during the period December, 1962 to May, 1969.

All three areas lie within the upper valley of Nungar Creek, a tributary of the Murrumbidgee River which it joins at Tantangara Dam. Nungar Plain is a closed cold-air drainage valley of restricted local relief (1,410m to 1,575m) with surrounding higher peaks.

General climate and vegetation have been described in a previous paper (Bryant, 1971).

TABLE 1

PERMITTED STOCKING LEVELS, NUNGAR PLAIN

Snow lease	Area (hectares)	1944 to 1958			1962 to 1969		
		No. sheep	No. cattle	Sheep equiv./ha*	No. sheep	No. cattle	Sheep equiv./ha*
E10	745	1,500	40	2·44	1,000	20	1·56
H10	502	1,000	30	2·47	900	10	1·95
B5	510	950	25	2·25	(900) Nil	Nil	(1·76) Nil

* 8 sheep = 1 head cattle

( ) proposed grazing levels

N.B. 1. Prior to 1944 no limitation was placed on stock numbers on leases.

2. Block B5 was not stocked in 1951 and 1952.

SNOW LEASE H10 (not including the unfenced C.R. 4350), comprises 502 ha on Nungar Plain at the head of the Nungar Creek. It has an altitudinal range of 1,424m to 1,516m (92m) with some 25 per cent of the total area lying above the 1,475m contour.

The area constitutes much of the valley floor and topography ranges from flat to undulating and hilly. Some 80–85 per cent of the area is accessible to stock. The main stream is slightly incised in a mature valley and has a typical meandering course. Minor streams are subparallel and flow southwards to their confluence with Nungar Creek. Soils are a catenary sequence of alpine humus and truncated bog soils over volcanic country rock.

The vegetation is predominantly treeless grassland with scattered shrubs and open woodland on the slopes above 1,475m. The valley floor is subject to severe frost, and in the wettest parts, to seasonal waterlogging. The grassland is snowgrass (*Poa clivicola*, J. Vickery) dominant with kangaroo grass (*Themeda australis*, Stapf.), wheatgrass (*Agropyron spp.*) and *Hovea longifolia* auctt (non A. Cunn). The open, partially

cleared woodland consists of white sally (*Eucalyptus pauciflora* Sieb ex Spreng.) dominant with associated black sally (*E. stellulata* Sieb ex D.C.) and scattered candlebark (*E. rubida* Deane & Maiden), while snowgrass (*Poa costiniana*, J. Vickery), *Calorophus lateriflorus*, F. Muell, *Scirpus spp.* and scattered *Sphagnum cymbifolium* Ehrh, and *Epacris spp.* form the bog communities.

SNOW LEASE E10. This lease comprises 745 ha on Nungar Plain to the south of Block H10 and extends from Nungar Creek to the Monaro Range. Altitudinal range is 1,427m to 1,635m, with at least 60 per cent of the area above 1,475m.

The central and eastern sections are lowly undulating, but become steeper to the west and south as a spur of the main range is approached.

Drainage is subreticulate to Nungar Creek; stream lines are slightly incised. Soils show catenary sequences of transitional alpine humus, prairie, fen and bog soils of frost-hollow valleys of the montane tract.

The lower limit of the treeline varies between 1,475m and 1,510m and the woodland is confined to the steeply undulating to hilly southern and western sections. There is evidence of extensive clearing prior to 1944. The grassland is dominated by snowgrass with associated wallaby grasses (*Danthonia spp.*), kangaroo grass, *Hovea longifolia*, with buttercups (*Ranunculus spp.*) and various *Compositae*. The woodland is dominated by white sally with associated black sally. The subordinate strata consists of snowgrass, hopbush (*Bossiaea foliosa*, A. Cunn.) and occasional silver wattle (*Acacia dealbata* Link).

SNOW LEASE B5. This consists of 510 ha on Nungar Plain to the south of Block H10, and west of Block E10, extending from Nungar Creek over the Monaro Range. Local relief is about 210m (1,425m to 1,635m) with 85 per cent of the area above 1,475m. The northern half slopes gently towards Nungar Creek and ranges from almost flat to lowly undulating, but the block becomes steeper in the southeast as it ascends a spur of the main range. Of the area, 65 per cent is within Nungar catchment while 80 per cent is accessible to stock.

Drainage is subradial from the Monaro Range with slightly incised streamlines. Soils are similar to those on Blocks E10 and H10.

Grassland vegetation ranges from snowgrass to snowgrass-kangaroo grass dominant with wallaby grass and composites. Woodlands and forests are dominated by white sally with associated black sally and mountain gum (*E. dalrympleana*, Maiden) in the forests. Subordinate strata is dominated by snowgrass with hopbush and silver wattle occasionally encountered.

On all three blocks the unpalatable grey-leaved snowgrass (*Poa phillipsiana*, J. Vickery) and *P. sieberana*, Spreng, occurred on eroded and denuded sites and the prostrate leguminous shrub *Pultenaea subspicata*, Benth. has colonized exposed ground situations.

LONG-TERM TRENDS

Methods

The possibility of tracing trends in erosion severity, and in vegetal cover patterns using black and white aerial photography was examined using photographs representing a time span of 26 years (1944 to 1970). Comparisons were carried out from aerial photographs taken in—

March, 1944. RAAF at a scale of 1:23,270

December, 1951. Adastra at a scale of 1:40,000

November, 1961. Lands Department of New South Wales at a scale of 1:37,800

April, 1970. Lands Department of New South Wales at a scale of 1:37,800

A mirror stereoscope (magnification x3) was used to classify ground cover into the five cover classes shown in table 2. Fortuitously, 1944 marked the end of a century of

TABLE 2

GROUND COVER CLASSIFICATION

Cover class	Cover range	Erosion class	Description
	per cent		
I	85–100	S–0	No sheet erosion.
II	60– 85	S–1	Minor sheet erosion.
III	40– 60	S–2	Moderate sheet erosion.
IV	20– 40	S–3	Severe sheet erosion.
V	Less than 20	..	Severe sheet erosion, some rilling.

uncontrolled grazing, 1961 was near the end of a short period of exclosure, and 1970 was one season after complete exclosure. The cover classes approximate the cover associated with sheet erosion classes used by the Soil Conservation Service of New South Wales in a number of surveys throughout the State (e.g. Taylor unpubl., Newman, 1954). Ground control for particular locations was available from permanent transect records for November, 1962 and November, 1969.

Results

Discernible changes in ground cover (with time) were observed (table 3).

TABLE 3

GROUND COVER ESTIMATES
SNOW LEASES E10, H10

Cover class	Cover range	Area (hectares)			
		1944	1951	1961	1970
	per cent				
I	85–100	303·5	647·5	643·5	708·2
II	60– 85	849·9	509·9	509·9	497·8
III	40– 60	93·1	85·0	85·0	32·4
IV	20– 40	..	4·1	8·1	8·1
V	Less than 20	..	..	..	..
Total ..	.. ..	1,246·5	1,246·5	1,246·5	1,246·5

(1) As well as the reduced cover, incipient grassland degeneration, consisting of a thinning of the turf of the dominant stratum, was apparent from the 1944 photographs. An unevenness of tone suggested the hummocky appearance of grassland associated by Costin (1954) with overgrazing by sheep.

(2) A partial recovery of class II lands followed the imposition of grazing control and the co-incidental end to a number of years of below average rainfall.

(3) Minor deterioration of former class III lands occurred during the period 1944 to 1951 and had increased by 1961.

(4) The period of exclosure (1958–1962) did not result in large-scale improvements in cover, although photographic tone indicated a possible improvement in condition of class I lands.

(5) Total exclusion of stock in 1969 followed by a season (1969–70) extremely favourable to establishment and growth resulted in considerable improvement to all except class IV lands. Field observations in 1970 revealed that this improvement in cover was to a considerable degree due to the unrestricted development of naturalized annuals and perennials (e.g. rat's tail fescue (*Vulpia spp.*) and sorrel (*Acetosella vulgaris*).

Discussion

It was impossible to accurately differentiate grassland associations from these photographs, although some forest and woodland associations could be determined on the basis of tonal contrasts. Major differences in grassland (e.g. wet sod-tussock and shrubs) could be determined.

Ground cover could be determined satisfactorily, but the accuracy was severely limited by the scale, so that areas less than approximately 1.5 ha. could not be mapped and areas less than 3 to 4 ha. were not accurately recorded by the dot grid method of area determination used.

A subsequent examination of alternative methods of recording vegetation and cover changes indicated that a linked 70-mm colour diapositive and infrared diapositive photographic technique at scales of 1:2000 or 1:5000 is worthy of assessment. This may allow rapid accurate definition of cover and condition of vegetation. Their use in mapping of vegetation associations is already well established (C. Totterdell, *et al.*, 1971).

TRANSECT STUDIES

Methods

In November, 1962, immediately prior to the re-introduction of grazing, eight permanent line transects were laid down on blocks E10 and H10.

In June, 1964, following the advent of fire as a management factor, a further seven permanent line transects were laid down on blocks E10, H10, and B5 as outlined in table 4.

Line intercepts of the total length of each class of vegetation were recorded using the colour photographic technique of Wimbush *et al* (1967). This method measures ground cover as the vertical projection of canopy using paired 35-mm colour diapositive photographs. It allows immediate objective comparison between years, and has the advantages of speed, accuracy, and permanent access to the original data. It does not, however, record all vegetation in multilayered communities.

Cover measurements were made twice each year—

(i) in late November, immediately prior to the commencement of grazing when the majority of native species had commenced growth and many had flowered, and

(ii) in early June, immediately after the completion of the annual grazing season.

TABLE 4

TRANSECT DETAILS

Original cover class	Transect				Grazing history	Burning history			
	Transect No.	Initial cover—per cent	Length (m)	Year commenced		5/64	3/65	5/65	5/66
I (85–100 per cent)	5	100·0	4·05	1962	Grazed	..	..	x	..
	8	100·0	4·05	1962	Grazed	x	xx	..	..
	12	100·0	4·05	1962	Grazed	..	..	..	..
	19	100·0	16·19	1964	Grazed	..	..	..	..
	20	74·6	16·19	1964	Grazed	x	..	..	..
	21	64·2	16·19	1964	Grazed	x	..	..	..
II (60–85 per cent)	1	80·6	12·14	1962	Grazed	..	..	..	..
	11	86·3	16·19	1962	Grazed	x	xx	..	..
	15	78·8	12·14	1964	Grazed	x	xx	..	..
	22	62·5	12·14	1964	Ungrazed	x	..	..	..
	23	62·6	16·19	1964	Ungrazed	x	..	..	..
III (40–60 per cent)	13	55·9	16·19	1962	Grazed	x	xx	..	..
IV (20–40 per cent)	3	29·3	26·71	1962	Grazed	..	..	..	..
	10	28·1	26·71	1962	Grazed	..	..	..	..
	14	24·3	17·81	1964	Grazed	x	..	..	..

x Control burn. xx Wildfire.

For analysis, cover components were grouped into the six categories of snowgrass, kangaroo grass, herbs, litter, shrub and bare ground.

Linear regressions were fitted to the data for per cent ground cover of herbs, and shrubs, litter, snowgrass, kangaroo grass, and bare ground in relation to the time since re-introduction of grazing.

Significance levels for the regression coefficients, each tested against its own residual mean, are given.

Results

Cover Class I

(1) Under grazing, ground cover decreased slightly from the maximum. Total cover, however, remained within the range of the "climax mean" as defined by Bryant (1969).

(2) The amount of cover contributed by herbs fell quickly, after the re-introduction of grazing, to levels about half the pregrazing level, and fluctuated seasonally. This was closely related to the reduced occurrence of buttercup (*Ranunculus graniticola*) and *Geranium sessiflorum.*

(3) The imposition of a controlled burn on to dense grassland swards caused an immediate decrease in total cover in excess of 22 per cent and recovery then varied from almost complete recovery to a continued deterioration. Where this deterioration took place it was closely related to fire damage to snowgrass.

(4) When grazed, shrubs decreased on those transects having the shrub *Hovea longifolia. Leucopogon hookeri* was not similarly affected by grazing.

Cover Class II

(1) Throughout the grazing period there was a gradual decrease in the amount of snowgrass present. The severe winter and drought of 1967 accelerated this decrease.

(2) On transects having a predominantly eucalypt leaf litter, litter cover varied from year to year. However, it tended to increase with time.

(3) Total ground cover fluctuated in response to variations in the amount of loose litter, but decreased overall.

(4) The transect affected by fire revealed a complex situation. Prior to burning total cover had remained relatively stable increasing from 85 per cent to 90 per cent. Controlled burning caused a 15 per cent reduction in total cover (related to damage to the snowgrass), wildfire the following year caused a further 13 per cent reduction in total cover. Total grass cover was reduced by 30 per cent under a controlled burn and 14 per cent by the subsequent wildfire.

(5) Recovery over the ensuing three seasons was 14 per cent total cover and 23 per cent grass cover but the after-effects of drought were severe. Recovery to prefire cover and condition did not occur under grazing even after 5 years.

Cover Class III

(1) Over the grazing period a progressive decrease (10 per cent) in the amount of snowgrass occurred. The proportion of the grey *Poa phillipsiana* remained constant.

(2) This was accompanied by a slow but inexorable deterioration in the amount of total snowgrass cover, though partially masked by the compensatory spread of the prostrate legume (*Pultenaea subspicata.*

Cover Class IV

(1) The snowgrass present was the grey-leaved *Poa phillipsiana,* a species generally shunned by stock. The snowgrass and kangaroo grass observed on less damaged areas was not present.

(2) Despite the low initial cover < 40 per cent) a continuing deterioration of about 0.5 per cent per season due to the snowgrass was apparent (figures 1a, 1b). Small decreases in total cover occurred despite some compensatory increases in loose litter and the prostrate legume *Pultenaea subspicata.*

(3) Herbs decreased initially following the re-introduction of grazing, thereafter, considerable within and between year variation occurred, with a net trend towards a lower contribution. Most common herbs were sorrel and *Viola bentonicifolia* Sm.

(4) Grazing produced spectacular seasonal effects with a net increase in the amount of loose litter-plus-bare ground of 11 per cent over a 7-year period, but a 5–7 per cent increase each year over the grazing season. Mean trends in ground cover with time for each initial cover class are shown in figure 2.

GRAZING EFFECTS ON VARIOUS INITIAL COVER CLASSES

Table 5 shows the net trends after grazing in the ground cover of grasslands, which had initially different ground covers, expressed as mean rates of change in ground cover. These have been calculated from the annual records of ground cover.

(1) Grazing resulted in an appreciable reduction in total cover irrespective of initial ground cover or of type of fire. The rates of decrease were of sufficient magnitude to cause serious concern.

(2) Cover relations of shrubs were complex and were related to the species present. When grazed small net decreases of *Hovea longifolia* were recorded. The small unpalatable heath *Leucopogon hookeri* remained constant. Burning caused large net decreases, but favoured the regeneration of *Leucopogon* over *Hovea.* Increases in percentages of shrubs were related to the invasion of bare ground by the shrub *Pultenaea subspicata* where initial cover was less than 60 per cent and herbaceous cover did not subsequently improve. Potentially, cover of this form **may** provide some protection of the soil against frost and dessication and may provide a preferred habitat for regeneration of the more delicate seedlings.

(3) Grazing selectively and dramatically decreased the proportion of herbs present.

TABLE 5

PER CENT CHANGE IN COVER COMPONENTS PER ANNUM UNDER GRAZING

Cover class and transect No.	Initial ground cover (per cent)	Initial snowgrass cover (per cent)	Mean change in cover components (per cent)					
			Snow-grass	Herbs	Litter	Shrub	Themeda	Total cover
I 12	100·0	50·8	+2·48*	−2·66†	−0·45	..	..	−0·97†
5	100·0	26·7	+3·69†	−1·46	+0·50	−3·71*	..	−0·97
8	100·0	81·7	−3·35*	−0·54	+0·74	..	..	−3·15‡
II 1	80·6	53·9	−3·15‡	+0·07	+1·07	..	..	−2·02*
11	86·3	55·0	−2·93	+0·24	+1·21	..	−1·01*	−2·50†
III 13	55·9	33·8	−0·61	+0·62	−0·25	+1·29*	..	+1·04
IV 3	29·3	18·1	−0·94†	−1·16‡	+0·90	..	..	−1·21*
10	28·3	11·7	−0·20	−0·61*	−0·58†	+0·28	..	−1·10*

Significance: * Significant p. = ·05. † Marginal p. ≦ ·05. ‡ Significant p. = ·01.

Figure 1a—Deterioration of grey leaved snowgrass (*Poa phillipsiana*) under grazing—cover class IV. 1962—immediately prior to re-introduction of grazing

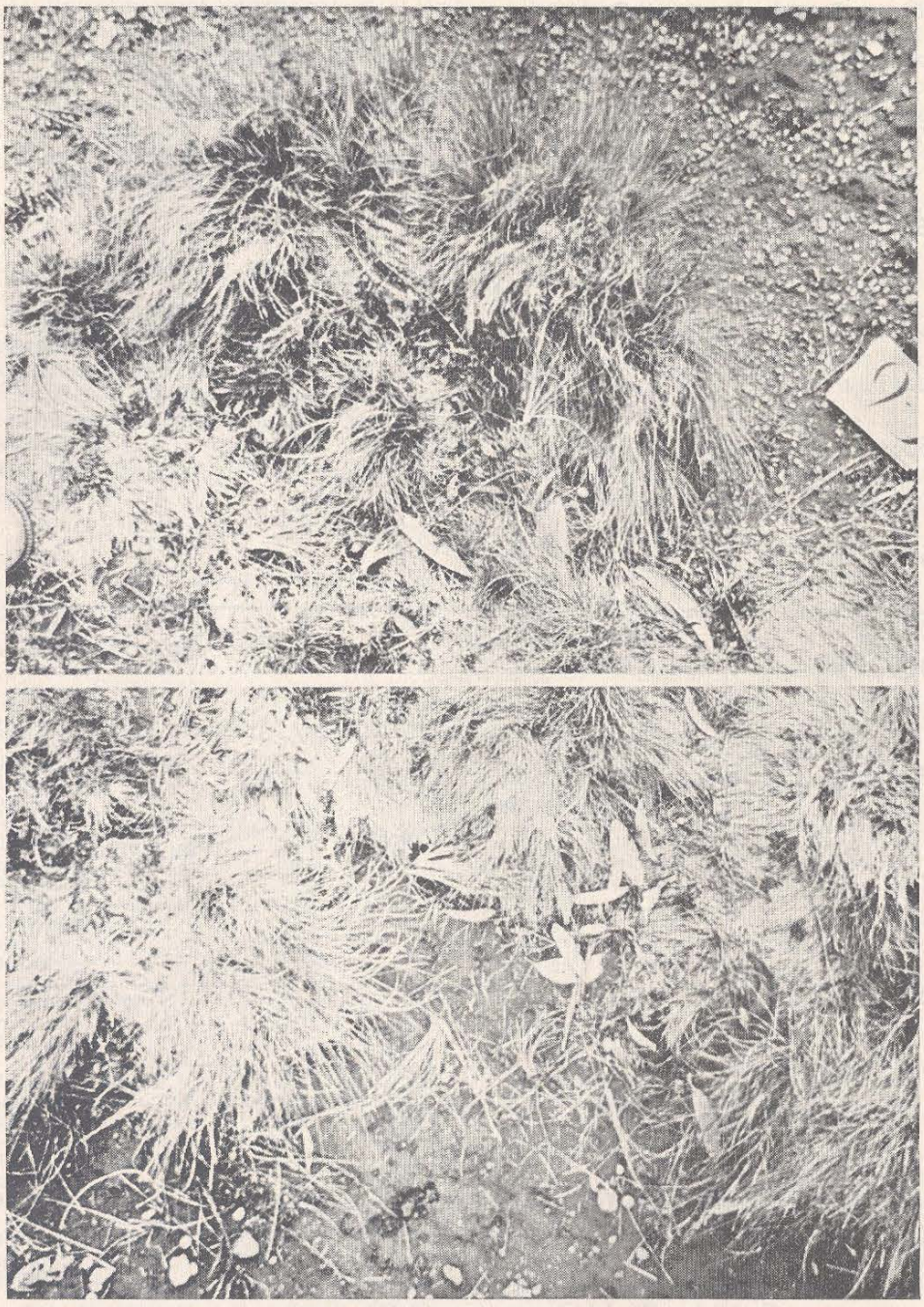

Figure 1b—Deterioration of grey leaved snowgrass (*Poa phillipsiana*) under grazing—cover class IV. 1968—after 6 seasons of grazing

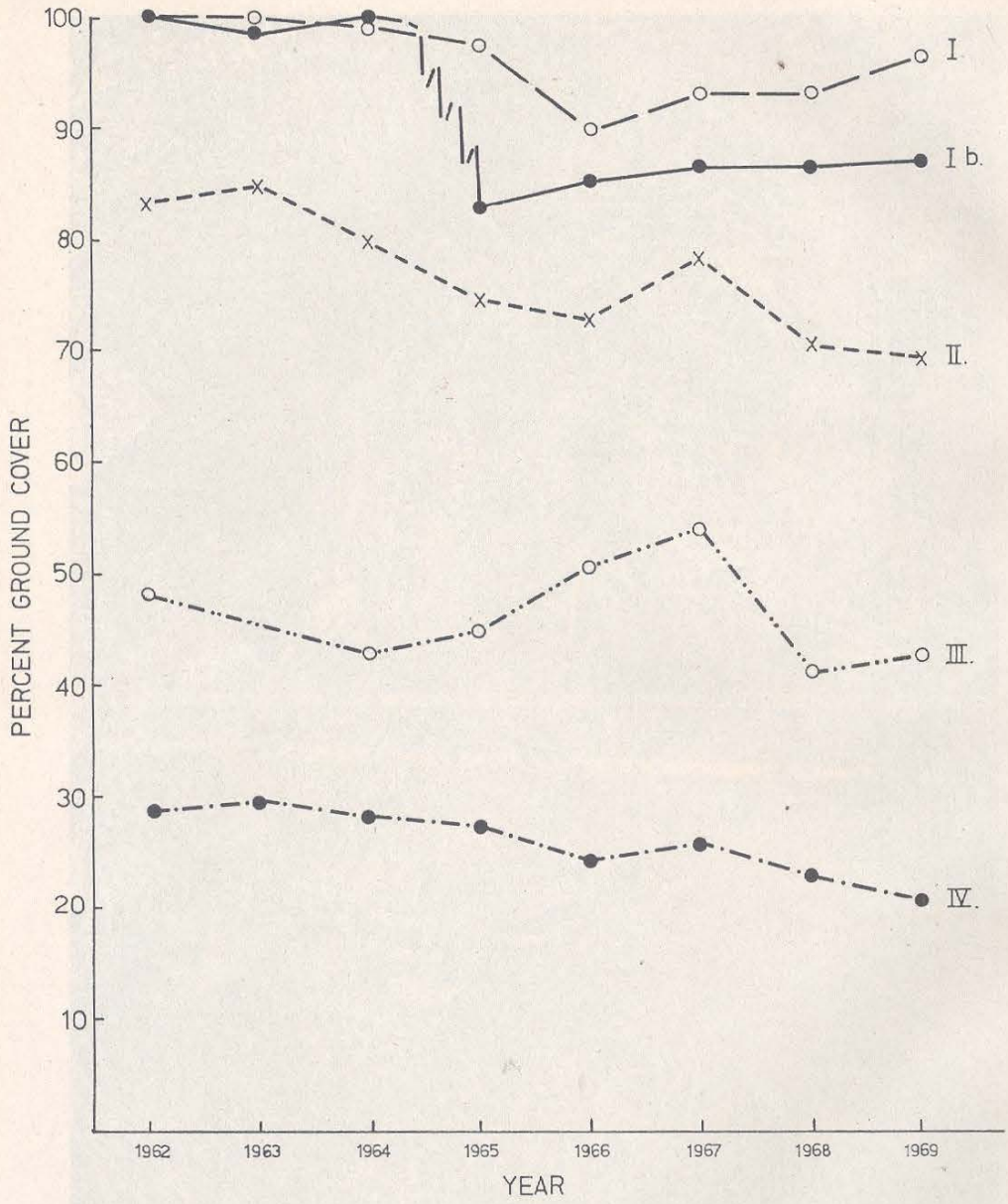

Figure 2—Trends in ground cover under grazing
Cover class I—initial cover range 85–100 per cent (unburnt)
Cover class Ib—initial cover range 85–100 per cent (burnt)
Cover class II—initial cover range 60–85 per cent
Cover class III—initial cover range 40–60 per cent
Cover class IV—initial cover range 20–40 per cent

(4) Rates of loss of cover appeared, at least in part, to be related to the initial cover and to subsequent burning history. Cover class II (60–85 per cent) suffered the most rapid deterioration under grazing, but was also the cover range most likely to recover quickly after exclosure (Bryant, 1969).

SEASONAL EFFECTS

Comparison of cover components over all grazed transects in November (start of grazing season) and in June (end of grazing season) has revealed less cover from herbs and snowgrass over the grazing season; increased loose litter mainly due to uprooted snowgrass (*Poa spp.*) tillers; and increased bare ground.

Partial recovery of these components occurred prior to the commencement of the next grazing season. However, irrespective of the main trend a positive relationship for cover loss was found. Table 6 presented seasonable litter plus bare ground data for six representative transects.

REGENERATION AFTER CONTROL BURNING

Net trends were derived by calculating the per cent change in cover per annum for each cover component for the 5-year period of regeneration after the particular event—in this case, a controlled burn. Table 7 records these trends.

The significance of these trends was tested by comparing the transect means for grazed and ungrazed areas by means of a

TABLE 6

SEASONAL INCREMENTS IN BAREGROUND PLUS LOOSE LITTER

	Bareground plus loose litter (per cent)					
	Transect 3	Transect 5	Transect 8	Transect 10	Transect 11	Transect 12
November, 1962	70·7	0	5·8	78·7	13·7	0
June, 1963	69·4*	2·5	15·2*	72·4*	31·3	4·0
Difference	−1·3	+2·5	+9·4	−6·3	+17·6	+4·0
November, 1963	68·8	2·5	5·0	76·6	11·7	8·3
June, 1964	71·7	0	14·8*†	78·4	27·3*†	0
Difference	+2·9	−2·5	+9·8	+1·8	+15·6	−8·3
November, 1964	70·0	11·7*	20·9*	76·9	36·0	13·3
June, 1965	75·8	0	16·4*†	80·9	28·9*†	0
Difference	+5·8	−11·7	−4·5	+4·0	−7·1	−13·3
November, 1965	72·0	18·6*†	28·4	79·8	51·7	19·2
June, 1966	82·3	38·3	38·3	82·7	46·6	20·0
Difference	+10·3	+19·7	+9·9	+2·9	−5·1	+0·8
November, 1966	77·5	23·3	27·5	77·4	32·1	13·3
June, 1967	83·7	17·6	26·7	81·8	45·4	9·9
Difference	+6·2	−5·7	−0·8	+4·4	+13·3	−3·4
November, 1967	79·7	23·3	24·2	76·5	31·7	16·7
June, 1968	83·6*	15·0	29·4*	86·6*	41·9*	23·4
Difference	+3·9	−8·3	+5·2	+10·1	+10·2	+6·7
November, 1968	81·5	5·0	30·0	80·9	51·4	13·4
June, 1969	87·3	29·3	32·5	86·4	40·6	15·9
Difference	+5·8	+24·3	+2·5	+5·5	−10·8	+2·5

* Estimated value. † Fire. L.s.d. (5 per cent) = 3·0.

TABLE 7

PER CENT CHANGE IN COVER COMPONENT PER ANNUM AFTER A CONTROLLED BURN

Class and transect No.	Initial ground cover	Initial snowgrass cover	Mean change in cover component					
			Snow-grass	Herbs	Litter	Shrub	Themeda	Total cover
Ungrazed 23 ..	67·7	51·1	−0·89	+2·38	−1·25	..	+3·95†	+4·20*
22 ..	67·5	38·1	−0·94	+1·13	−1·70	+0·14	+5·42*	+4·06*
Mean ..			−0·91	+1·75	−1·47	..	+4·68	+4·12
Grazed 15 ..	78·8	51·1	+0·11	−0·31	−1·12	..	−0·55	−1·87
11 ..	75·0	40·2	+0·85	+0·09	−0·40	..	−0·68	−0·13
Mean ..			+0·48	−0·11	−0·76	..	−0·60	−1·00
Significance of Mean Treatment Differences ..			NS	NS	NS	NS	0·1%	1%

Significance of trend: * p. ·05. † p. ·01.

t-test of their respective regression coefficients. The levels of significance are indicated in table 7.

The great differences in postfire trends in total cover were immediately apparent. Irrespective of grazing treatment, control burning adversely affected the subsequent development of snowgrass. Irrespective of subsequent treatment, a control burn stimulated herb development, probably as a result of increased light penetration and decreased competition. Kangaroo grass increased dramatically after controlled burning where grazing stock were excluded, but remained a minor component or actually decreased in the presence of the grazing animal.

DISCUSSION

Stocking intensities at Nungar in the period 1962 to 1969 were considerably less than those which presumably caused deterioration to the levels observed in the 1944 and 1951 aerial photographs. These levels prompted Taylor (unpubl.) to report that all three blocks were seriously overgrazed and that sheet erosion was serious, particularly in the southeast corner of Block H10 and the western section of E10.

It is unlikely, then, that deterioration recorded in the period 1962 to 1969 was more severe or more rapid than that occurring between 1944 and 1958 and especially in the pre-1944 era of uncontrolled grazing and frequent control burning.

The four-season exclosure from grazing (1958–1962) can best be regarded as a stabilizing period when downward trends would, at best, have been halted. This has been confirmed by the general trends revealed by the aerial photographs. Bryant (1969) gives recovery periods of approximately 10 to 40 years where the initial cover is 60–85 per cent (cover class II); 40 to 65 years where the initial cover is 40–60 percent (cover class III); and 65 to 90 years for 20–40 per cent initial cover (cover class IV). This parallels Wraight's (1963) findings in the alpine and montane grasslands of the Wairau Catchment (New Zealand). Land management practices likely to cause further deterioration in cover would only lengthen the time required for recovery and increase the exposure of bare ground to the risk of erosion losses.

Costin *et al.* (1960), examined runoff and erosion losses from a number of grassland sites in the alpine and subalpine tracts

of the Snowy Mountains. Their data may be compared to the cover classes considered here (table 8). It would seem likely that soil losses would exceed manageable proportions when ground cover decreased to about 60 per cent. McArthur and Cheney (1965) reported that plots in the Cotter River Catchment showed rapid increases in soil loss when the percentage of ground cover dropped below 60 per cent.

From figure 3, a mean loss of cover exceeding 2 per cent per annum could be expected if total ground cover was between 85 per cent and 40 per cent at the time of re-introduction of grazing. Within as brief a span as 20 years, cover could deteriorate to only 20 to 40 per cent. The area would then require a predicted recovery period exceeding 65 years (Bryant, 1969), provided erosion losses were not so severe as to prevent or to seriously retard recolonization. For much of the recovery period (up to thirty years) the area would be subject to potential erosion losses exceeding 5 tonnes per hectare (Costin *et al.*, 1960).

Sheep grazing for seven years caused a continued deteriorative trend in cover (which approached 2 per cent per annum) over all except the densest vegetation class (class I).

This deterioration was due to the grazing of palatable herbs and kangaroo grass and to the increased amounts of loose litter resulting from uprooting of snowgrass tillers by grazing sheep. The effect of cattle grazing in highland areas of Victoria reported by Carr and Turner (1959) would appear to be less detrimental than the effects of sheep grazing, recorded by various authors, in the Snowy Mountains.

On areas having a complete cover initially, variations under grazing were within the accepted limits for the class, unless they were burnt by either controlled burning or by wildfire. Grazing of such undamaged dense, swards might then be acceptable if it were not for associated deterioration of adjacent areas with less dense initial cover.

Occasional light grazing (one season in ten) on areas normally excluded from grazing caused an immediate decrease in cover but had no lasting effect on areas which were initially densely covered. Such grazing of grassland may be a more acceptable alternative than controlled burning.

The effects of a controlled burn in late autumn on both grazed and ungrazed grassland was to initiate deterioration of snowgrass and to stimulate the growth of inter-tussock herb species. Associated spectacular increases were recorded in kangaroo grass to levels approaching subdominance in the absence of grazing, but it remained a minor species in the presence of grazing. The reasons for this are not clear, but they may well be related to the greater efficiency of kangaroo grass in utilizing fire-mobilized nutrients (Ehrenreich and Aikman, 1963), and to the timing of the burn to late autumn potentially favouring its dominance as it does *T. triandra* in the high-veld of South Africa (Staples, 1930; Coetzee, 1942; West, 1965).

TABLE 8

GROUND COVER—EROSION LOSS RELATIONS
SNOWY MOUNTAINS GRASSLANDS

Cover class	Cover range	Per cent of total area (1961)	*Projected time of complete recovery	†Mean cover	†Mean soil loss 1956–58
	per cent	per cent	years	per cent	tonnes/ha
I	85–100	51·6	10	100	Nil
II	60– 85	41·9	10–40	70	4·39
III	40– 60	6·7	40–65	..	..
IV	20– 40	0·7	65–90	20	13·38
V	0– 20	Nil	90	10	94·41

* After Bryant (1969), figure 6. † Costin *et al* (1960), table 1.

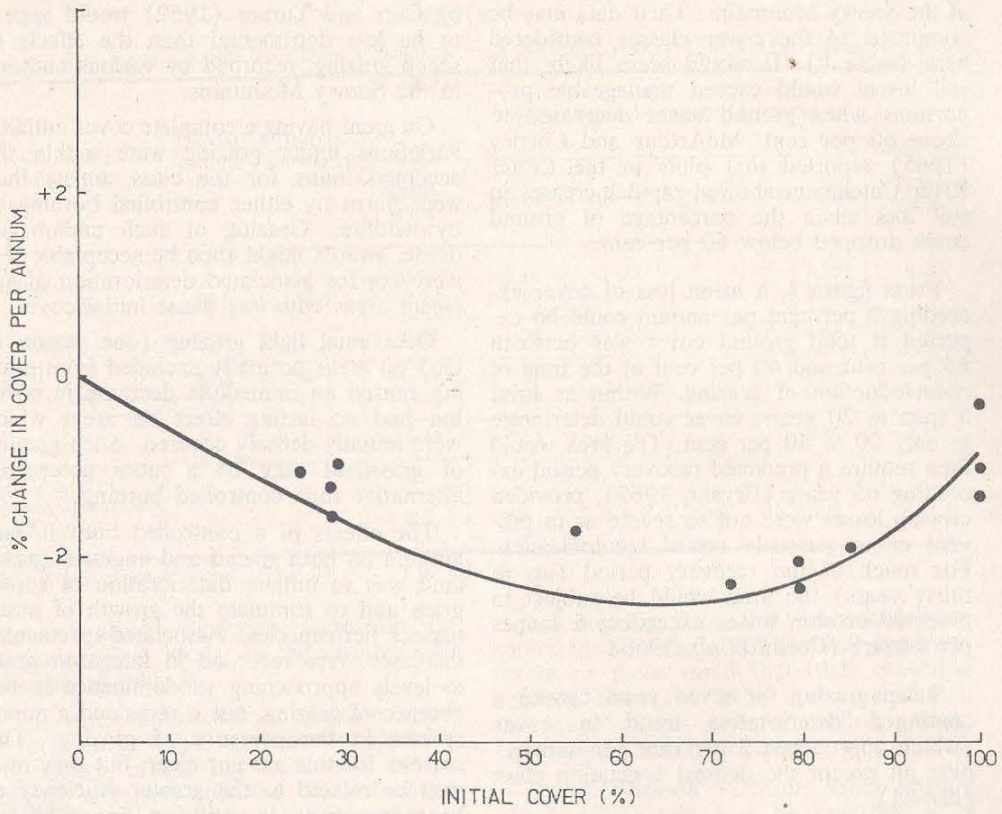

Figure 3—Rates of deterioration of ground cover over a 7-year period (1962–1969) under grazing

The amount of cover on ungrazed grasslands had substantially recovered to prefire levels after four seasons and compared well with data obtained elsewhere in humid prairie areas (Vogl, 1965). Similarly, a postfire period of at least 3 years without grazing was required before New Zealand snow-tussock (*Chionochloa rigida*) recovered to a condition similar to the unburnt canopy (O'Connor and Powell, 1963).

After burning in two succeeding seasons, grazed grassland had not recovered after five seasons (table 7); it had continued to deteriorate on all areas except those having the best initial cover.

It is apparent from the results that occasional light grazing of mountain grasslands such as these might be undertaken to reduce the amount of growth without causing lasting damage to the communities. However, regular summer grazing of sheep cannot be accepted as wise land-use in areas where the primary values are water catchment and National Park purposes.

A single controlled burn, intelligently used, may provide an opportunity to manipulate the vegetation composition and to promote increased herb cover, and to stimulate flowering of certain species. O'Connor and Lambrechtson (1964) have

obtained better clover establishment in the lee of unburnt tall tussocks than on the burnt bare spaces, although in other mountain areas a late autumn burn has been considered a useful preliminary to fertilization and oversowing with clovers.

It must be recognized that the use of fire is likely to be detrimental to the continued persistence of snowgrass and, when used as a management tool associated with grazing, can quickly initiate deterioration of vegetation which may be difficult and slow to halt or reverse.

It is important to realize that most of the grassland and grasslands beneath white sally woodland described in this paper fall within categories (ii) and (iii) of the 1971 revision of the Hume-Snowy Fire Control Plan (Anon., 1971). These are:

(ii) (a) forests and woodlands above 1,475m;

(b) alpine and subalpine grasslands—in which strip burning up to 300m in width may take place;

(iii) forests and woodland areas below an elevation of 1,475m—where control burning may be practised on a broad acre basis.

These results do not indicate that protection from fire and grazing would increase fuel loads of flammable woody shrubs. The results do point however, to the potential damage to ground cover and to the changes in species composition that can be wrought by fire, either controlled or uncontrolled, and by grazing. Since other workers have found close relations between erosion losses and ground cover, it seems unwise to adopt practices likely to directly decrease ground cover, or indirectly, to initiate processes leading to decreased ground cover.

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