# VEGETATION AND GROUND COVER TRENDS—FOLLOWING THE EXCLUSION OF STOCK AT THREE SITES IN THE SNOWY MOUNTAINS, NEW SOUTH WALES

BY

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*Since 1953, the Soil Conservation Service of New South Wales has maintained a number of regeneration areas in the catchments of the Snowy Mountains to investigate regeneration patterns in snowgrass tussock grassland and snowgum woodland after exclusion from grazing.*

*Following the removal of livestock the following trends were found: increased regeneration of snowgum seedlings; decreased shrub component on the deeper soils, the pattern of decrease being dependent upon the species of shrub encountered; regression towards the climax mean ground cover in both stable and open snowgrass tussock swards.*

Sheep and cattle grazing during spring, summer, and autumn, accompanied by periodic burning of the grasslands, woodlands, and forest communities has been the traditional land-use of the high mountains of southeast New South Wales for nearly a century.

Since the advent of the $800 million Snowy Mountains Hydro-Electric Scheme, there has been renewed interest in the vegetation, stability, and use of these catchment areas (Costin, 1954, 1957; Costin *et al,* 1959, 1960, 1961). These investigations and reappraisals of the effects of grazing in relation to catchment values have formed the basis of submissions by scientists, conservation groups, government agencies, and national grazier organizations for protection (partial or complete) of the mountain catchments. Such proposals have been met by strong resistance from local groups and individuals having traditional interests in unrestricted use of the area for grazing, timber getting, etc. In order to protect the higher alpine and sub-alpine areas from serious erosion, which was already evident in many areas, grazing of areas generally above 4,500 feet was prohibited in 1958.

Surveys of the extent of erosion damage (Newman, 1955; Taylor, 1957) and of vegetation deterioration (Costin *et al,* 1959; Bryant, 1968), have been made. Taylor (1956) has commented upon the history of grazing management and its effects, and has endeavoured to evaluate the arguments concerning burning and grazing. More recent work has aimed at delineating the conditions necessary for catchment stability and improvement (Costin *et al,* 1960), and developing techniques for erosion control (Clothier and Condon, 1968).

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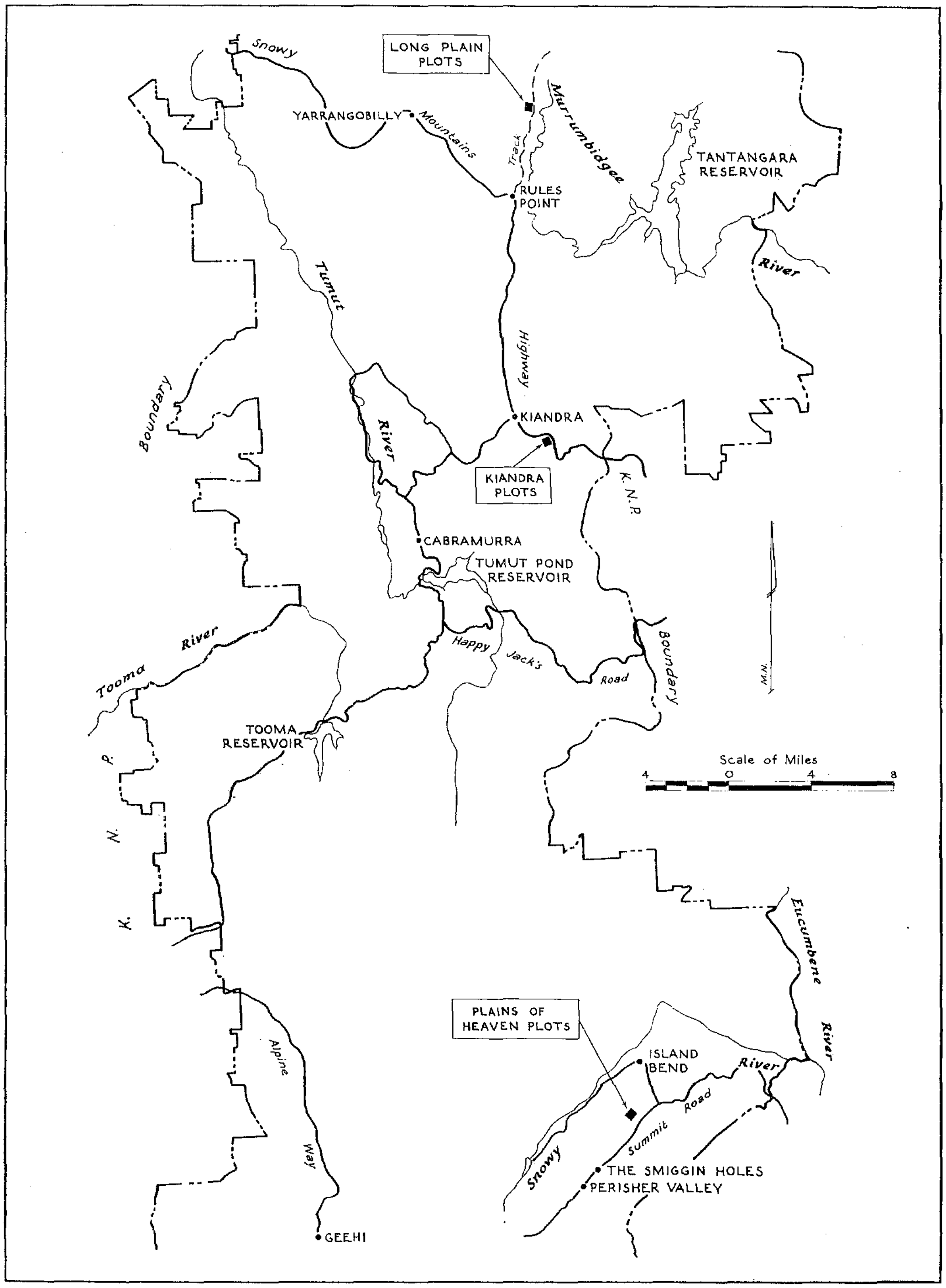


*Figure* 1.—The Snowy Mountains showing the location of the study areas

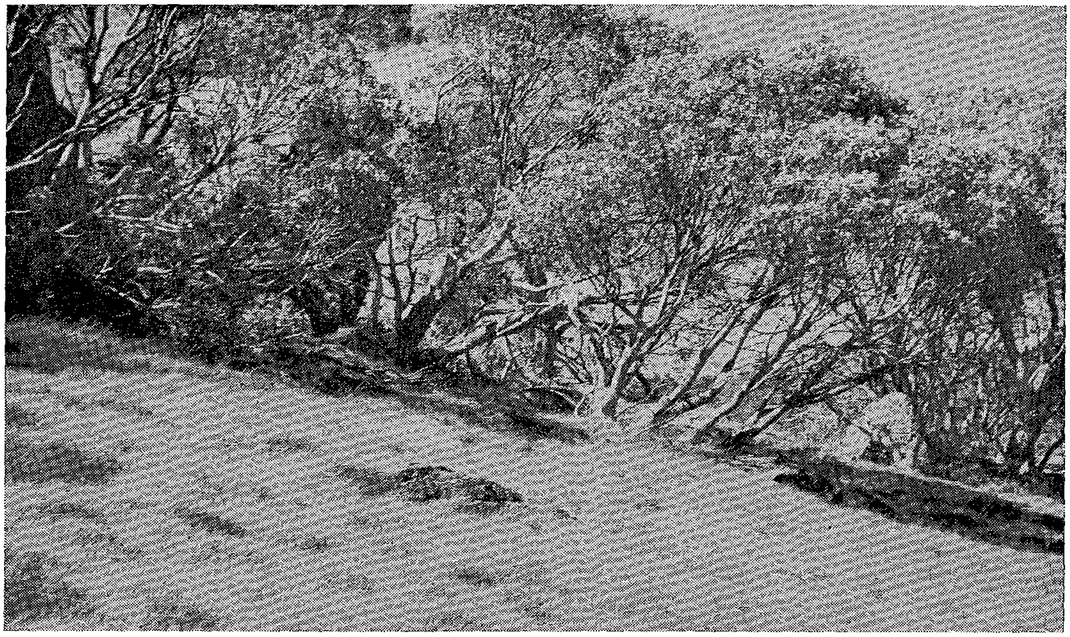

*Figure 2.*—Sub-alpine Woodland that has been protected from grazing

It is now generally recognized that the Snowy Mountains are of such importance as a source of power and water that only one primary management objective is permissible—water yield of high quality. All other objectives (grazing, timber production, recreation) must be secondary and, where shown to be deleterious to catchment values, must be modified or removed. Costin (1965) reports potential values of $40–$90 per acre for hydro-electric power and irrigation water in comparison with grazing values of $0.50–$2.00 per acre per annum.

Contentions that grazing and burning are not deleterious to catchment values have been reported (Newman, 1954; Taylor, 1956), and in the local press.

In an attempt to trace regeneration patterns on snowgrass (*Poa caespitosa* Forst. F.) tussock grassland and in adjacent white sally (*Eucalyptus pauciflora* Sieb. ex Spreng) woodlands the Soil Conservation Service has, since 1953, maintained a number of regeneration study areas.

This paper reports the results from studies on three such areas, representing two "frost valley" grasslands and adjacent woodlands of 4,400–5,000 feet elevation in the northern portion of the Kosciusko National Park and one area of open sub-alpine woodland and snowgrass tussock grassland at an altitude of 5,600 feet in the southern portion of the park.

## METHODS

Studies were carried out at three sites (figure 1).

(i) Long Plain.—5¼ miles northeast of Rules Point at a height of 4,500 feet on the edge of a large "frost valley" in the headwaters of the Murrumbidgee River. Vegetation is snowgrass dominant grassland merging up-slope into open sub-alpine woodland with shrubs such as hop bush (*Bossiaea foliosa* A. Cunn.), snowgrass and other herbs on shallow alpine humus soil over basalt. An area of 15.1 acres was fenced out from grazing in January, 1954.

(ii) Kiandra.—One mile southwest of Kiandra, adjacent to the Snowy Mountains Highway at a height of 4,400 feet on the undulating slopes of a frost valley above the

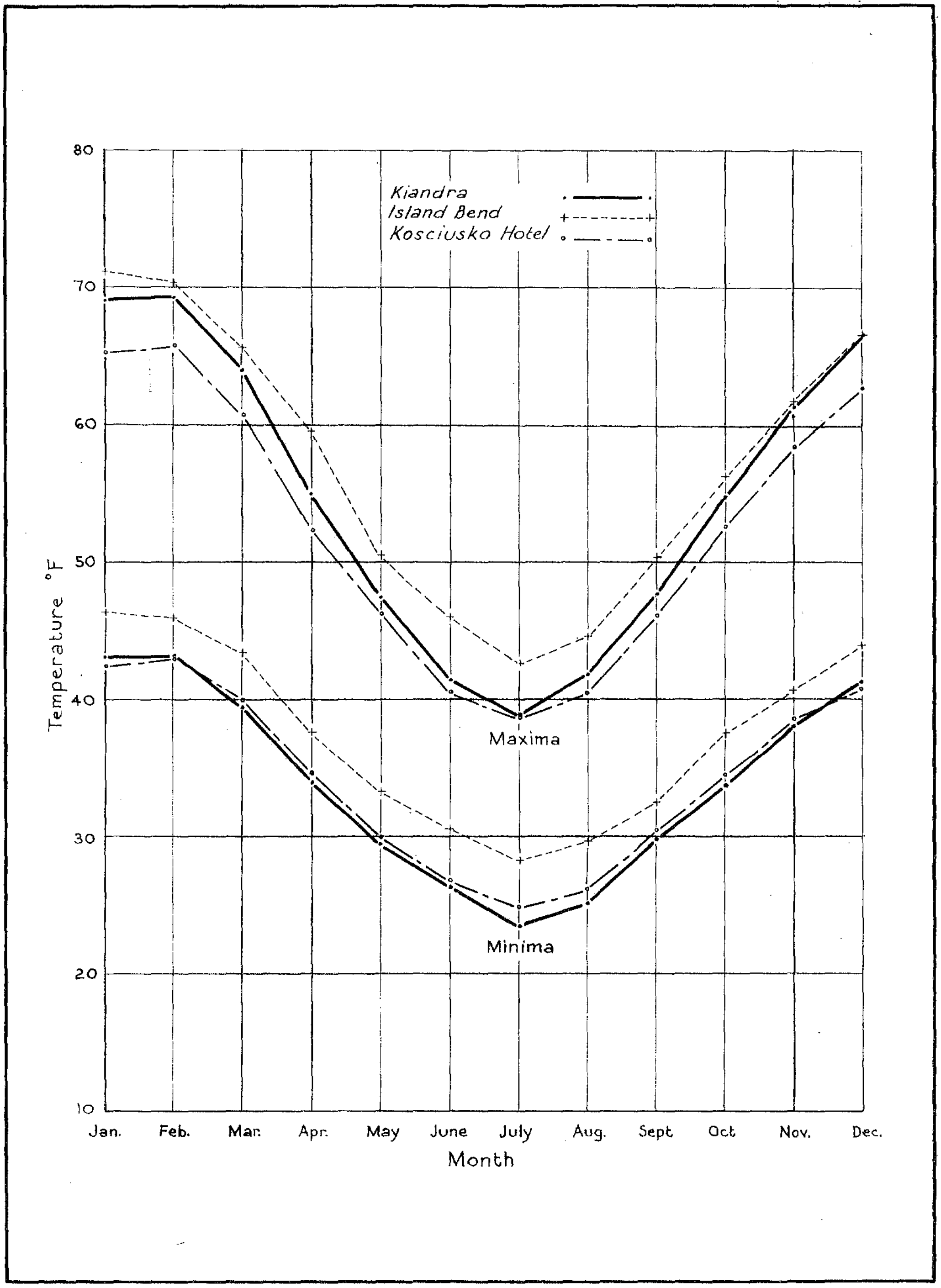


*Figure* 3.—Mean monthly maximum and minimum temperatures for selected stations on the Snowy Mountains


*Figure* 4.—Mean monthly precipitation for selected stations on the Snowy Mountains

Eucumbene River. This area of 17.2 acres was also excluded from grazing in January, 1954, but was subject to moderately heavy grazing by rabbits until 1957. Soil is alpine humus over basalt.

(iii) PLAINS OF HEAVEN.—Approximately $\frac{1}{2}$ mile northwest of Dainer's Gap above the Kosciusko Road at a height of 5,600 feet. Open snowgrass grassland with some open depleted sub-alpine woodland snowgum (*Euc. niphophila* Maiden & Blakely) with shrub (*Pimelea spp., Hovea longifolia* (auctt non. A. Cunn.), *Prostranthia cuneata* Benth.), and snowgrass understory. Excluded from grazing in 1952, the area of 20.6 acres was subsequently illegally grazed until January, 1955. Soils are alpine humus with granodiorite outcrops over granodiorite.

Temperature and rainfall data per the closest available meteorological stations are summarized in figures 3 and 4.

The climate of the three sites is characterized by mild summers (mean maxima for the hottest month 65°–72°F), and a growing season restricted to 5 to 6 months' duration between October and May. Winters are cold with a high incidence of severe frosts (150–160) extending into the growing season. Snow cover varies from non-persistent to several months depending upon year and altitude. The two northern sites (Kiandra and Long Plain) seldom experience persistent snow for more than 1 month's duration. The southern site (Plains of Heaven) experiences light to moderate snow of 1 to 3 months' duration.

Precipitation is of the order of 40 in-60 in per annum with a late winter maximum and a late summer-early autumn minimum.

Permanent reference areas were established. These were line intercept transects, and quadrats, to study the effects of exclosure on:

(1) Snowgrass tussock grassland of both open and closed canopy at Long Plain, Kiandra, and Plains of Heaven.

(2) Open woodland (white sally/snowgum) with mixed shrub and herbaceous understorey at Long Plain and Plains of Heaven.

(3) Open to closed woodland (white sally) with stand regenerating from seedlings.

TABLE 1

DISTRIBUTION OF SNOWGRASS REGENERATION QUADRATS

| | Closed sward | Open sward | |
|---|---|---|---|
| | 90 per cent cover | 40–60 per cent cover | 0–20 per cent cover |
| Long Plain ... | 2 | 2 | ... |
| Kiandra ... ... | 4 | 2 | 2 |
| Plains of Heaven... | 3 | 4 | ... |
| Total ... | 9 | 8 | 2 |

## SNOWGUM SEEDLING REGENERATION

### Methods

Twenty-eight pairs of belt transects, each transect 3 feet by 34 feet were laid down adjacent to, and each side of the enclosure fence at Long Plain to measure the numbers of regenerating snowgum seedlings.

The transects were laid down beneath an even-aged snowgum woodland. Seedling numbers were measured annually from 1954–58, 1963, and 1965–68. Some 21 mature trees were close enough to overhang the plots and to have shed seed, 10 of them inside and 11 of them outside the excluding fence.

For analysis, each four consecutive plots were grouped to give grazed and ungrazed seedling counts for each year of record in seven pairs of main plots. As the level of regeneration varied considerably a relative rate of change index was adopted of the form (G. A. McIntyre, pers. comm.). (4(1968) + 3(1967) + 2(1966) + 1(1965) + 0(1968) — 1(1957) — 2(1956) — 3(1955) — 4(1954) 1954 to 1968.

## Results

1. The change rate (table 2) is different for the two treatments, the ungrazed showing a small average increase with time, the grazed a definite decrease.

The difference in trend is significant at P 0.01.

2. The gross numbers (table 3) show a rapid increase in seedling numbers upon the exclusion of stock with relatively constant numbers thereafter. This is related, in all probability, to the increase in size of individual seedlings inhibiting (by competition) further establishments.

3. Lower seedling numbers were recorded in drier years. In an attempt to explain these figures, rainfall deviations from the mean in the October-April growing season have been plotted against deviations from the mean number of seedlings.

TABLE 2

RELATIVE RATE OF CHANGE INDEX

| | Ungrazed | Grazed | Total |
|---|---|---|---|
| I ... | +0.0451 | —1.4474 | —1.4023 |
| II ... | +0.3055 | —2.6667 | —2.3612 |
| III ... | +0.2986 | —0.7727 | —0.4741 |
| IV ... | +0.5211 | —0.1000 | +0.4211 |
| V ... | +0.2222 | 0.0000 | +0.2222 |
| VI ... | +0.4035 | 0.0000 | +0.4035 |
| VII ... | +0.3511 | —0.9259 | —0.5748 |
| Total ... | +0.21471 | —5.9127 | —3.7656 |

Significance level P 0.01.

## Discussion

After almost a century of grazing by both sheep and cattle, there is continued effective control of regeneration of seedlings of white sally. The removal of stock results in a rapid and significant increase in the number of seedling snowgums establishing and persisting.

The lack of randomization in siting of grazed and ungrazed plots may be regarded as a statistical shortcoming. However, since similar relations are being obtained from more recent studies on similar country at Nungar High Plain, some 14 miles to the south-east, these results appear valid.

TABLE 3

TOTAL COUNTS SNOWGUM REGENERATION LONG PLAIN

| Year | Ungrazed | Grazed | Total |
|---|---|---|---|
| 1954 ... ... | 74 | 47 | 121 |
| 1955 ... ... | 142 | 37 | 179 |
| 1956 ... ... | 140 | 27 | 167 |
| 1957 ... ... | 118 | 15 | 133 |
| 1958 ... ... | 91 | 15 | 106 |
| 1965 ... ... | 130 | 8 | 138 |
| 1966 ... ... | 147 | 12 | 159 |
| 1967 ... ... | 143 | 26 | 169 |
| 1968 ... ... | 139 | 10 | 149 |
| Mean ... | 124.9 | 21.8 | ... |

The management inference is therefore, that to maintain the rigorous stand of snowgum essential to efficient catchment management, open, even-aged, woodland should be closed to grazing periodically to allow replacement of over-aged, fire, and storm weakened trees. No measurements have been made on the length of time for seedling regeneration to attain a size sufficient to protect them from the depredations of the grazing animal. However, at Nungar, areas protected from grazing for as little as 6 years have carried snowgum regeneration up to 6 to 8 feet in height. These have been little damaged by grazing sheep following the re-introduction of grazing.

Low figures in the plots protected from grazing in certain years may be explained in terms of the percentage deviations from the mean precipitation for the growing season. These are secondary to the main grazing effects. The grazing treatment masks this relationship on the unprotected plots.

## SHRUB TRANSECTS

### Methods

Line intercept transects were laid down at both Long Plain and Plains of Heaven to examine the pattern of shrub development following exclosure. Canopy projection was measured each year except for 1959–1962 and 1964.

Five line transects, each one chain in length, were laid down at Long Plain. Each transect had as its shrub component hop bush under open woodland; ground cover consisted of snowgrass, herbs, and both eucalypt and herbaceous litter. Transects 1, 2, 4, 5, were located on shallow transitional alpine humus soil of the upper slopes of a low ridge. Transect 3 was located on a stony open site on the ridge line.

Four, one chain long line transects were laid down at Plains of Heaven. Transects 1, 2, and 3 had shrub components of *Pimelea spp.*, and *Hovea longifolia* auc.H. (non A. Cunn.) under degenerate open subalpine woodland (snowgum) on shallow alpine humus soils with numerous rocky outcrops. Transect 4 had as its main shrub component *Prostranthera cuneata* Benth. and *Pimelea spp.*

Linear regressions were fitted to the integral since exclosure for percentage shrub cover, and co-efficients calculated. Transect 3 from Plains of Heaven was discarded as records were not available after 1958.

Results are summarized in table 4.

## Results

Most transects, having initially 15–30 per cent shrub cover, show an increase in shrub component, reaching a maximum value within three years of exclosure. Thereafter there is a continued decline in the amount of shrub where *Bossiaea*, *Hovea*, or *Pimelea* is the dominant shrub. The initial increase is related to increased development of existing shrubs rather than increased numbers, and the decline to loss of vigour and ultimate death of plants.

Transect 3 at Long Plain is seemingly atypical, showing a continued significant increase in shrub component with time.

On the one transect where *Phebalium* was the main shrub, the maximum shrub cover was not reached until 5 years after exclosure. Subsequent decline was variable, but after 15 years it had declined to a level little different to the initial figure.

TABLE 4

SHRUB COVER (%) VARIATIONS AFTER EXCLUSION FROM GRAZING

| | Long plain | | | | | Plains of Heaven | | |
|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T3 | T4 | T5 | T1 | T2 | T4 |
| Dominant shrub | Bossiaea | Bossiaea | Bossiaea | Bossiaea | Bossiaea | Pimelea/ Hovea | Pimelea/ Hovea | Phebalium /Pimelea |
| 1953 ... ... | ... | ... | ... | ... | ... | 17.5 | 18.5 | 22.5 |
| 1954 ... ... | 18.0 | 33.0 | 22.0 | 14.5 | 21.5 | 18.0 | 22.0 | 27.0 |
| 1955 ... ... | 24.0 | 28.0 | 30.0 | 15.0 | 20.0 | 17.5 | 19.5 | 30.0 |
| 1956 ... ... | 25.0 | 25.0 | 32.5 | 14.5 | 18.5 | 15.0 | 20.5 | 28.0 |
| 1957 ... ... | 23.0 | 28.0 | 39.0 | 17.0 | 19.0 | 14.0 | 19.0 | 34.0 |
| 1958 ... ... | 24.5 | 22.0 | 38.0 | 15.0 | 18.0 | 14.0 | 17.0 | 27.0 |
| 1963 ... ... | NR | 17.4 | 29.7 | 10.7 | 16.4 | 17.9 | NR | 23.7 |
| 1965 ... ... | 15.0 | 22.2 | 39.8 | 11.6 | NR | 3.0 | 13.5 | 24.5 |
| 1966 ... ... | 14.4 | 22.9 | 44.4 | 9.2 | 10.1 | 2.9 | 13.1 | 25.2 |
| 1967 ... ... | 12.1 | 22.1 | 48.5 | 7.1 | 13.3 | 2.3 | 11.9 | 25.4 |
| Regression co-efficient ... | —8.065* | —6.473* | —2.112* | —5.684** | —6.852*** | —10.713*** | —6.067*** | —2.14 |
| Correlation co-efficient ... | —0.824* | —0.723* | 0.755* | —0.894** | —0.933*** | —0.848* | —0.937*** | —0.339 |

*Figure* 5.—Eucalypt regeneration on the Long Plain experimental area. Stock have been excluded from the area on the right

## Discussion

The results presented suggest three separate situations.

1. Six transects representing two widely different situations, dominated by either *Bossiaea* or *Hovea* and *Pimelea* show an initial increase in per cent ground cover due to shrub, followed by a significant decline with time. The expectation that removal of grazing and burning would encourage shrub growth is *not* supported by these results.

The more probable alternative situation is that shrub invasion is favoured when the natural snowgrass sward has already been opened up or lost by repeated burning and grazing. An interesting case in point is the CSIRO plot at Boggy Plain where areas mechanically denuded of snowgrass 10 years ago, now carry a vigorous shrub cover with snowgrass and herbs slowly re-colonizing areas beneath the shrubs (D. J. Wimbush, pers. comm.).

2. One *Bossiaea* dominant transect has shown a continued significant tendency to increased shrub dominance. This transect is located on a dry stony site having much bare ground. It is significant that throughout the mountains natural shrubberies occur in these situations which are apparently more suited to deeper rooted woody species than to the denser rooting herbs.

3. The difference in shrub cover trends between the transects having *Bossiaea* or *Hovea* and the one having *Phebalium* as the dominant shrub may be explainable in terms of the length of the life cycle of the shrub component. As further shrub species are studied it may be expected that patterns of varying durations will be observed.

It is not clear from this study, however, whether it is protection from grazing, or burning or both, which results in the development of the observed patterns. Certainly the removal of burning allows completion of shrub life-cycles, whilst removal of grazing may remove a pre-disposing cause of shrub invasion—lack of competition.

The most significant structural implication of these studies is that on relatively

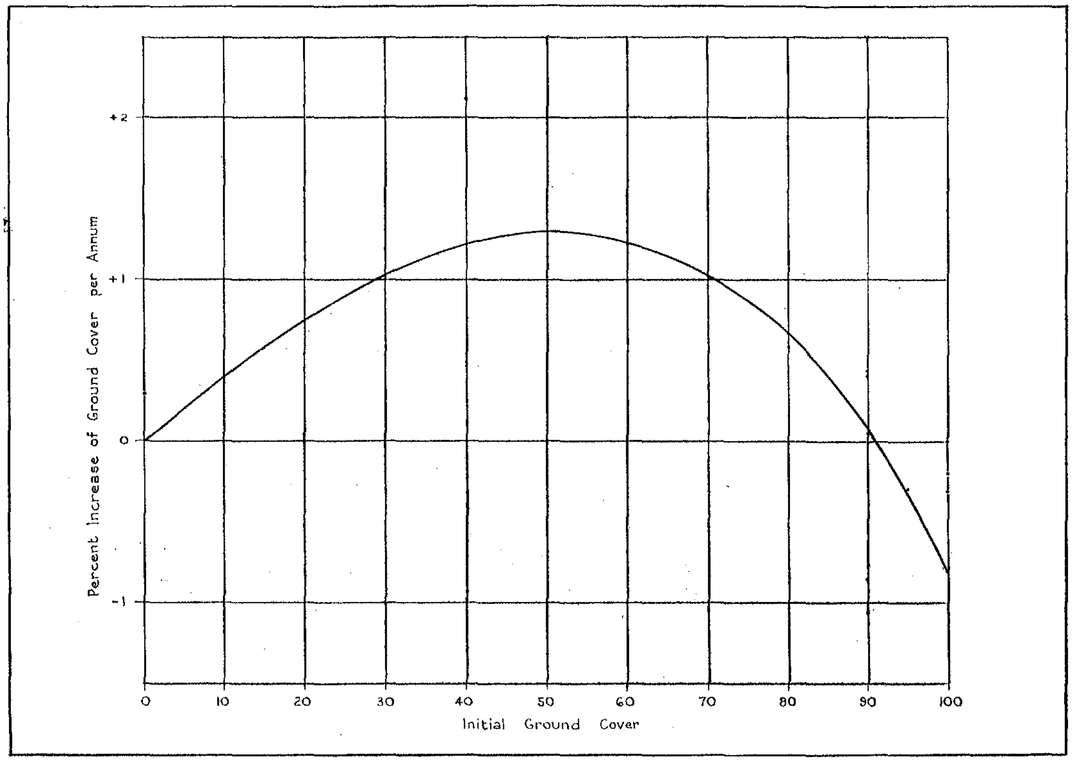


*Figure* 6.—Ground cover recovery rates over a fifteen-year period

stone-free soils protection from grazing and burning has not resulted in a large increase in the shrubs, but rather has there been a relative increase in herbs.

## GRASSLAND REGENERATION

### Methods

Some 25 permanent quadrats each 10 feet by 5 feet were laid down at the three sites, Long Plain, Kiandra, and Plains of Heaven. Cover components were measured annually (except 1959–1962, 1964) in early March and grouped into five categories—snowgrass, herbs, shrubs, litter, and bare ground.

Linear regressions were fitted to the interval since exclosure for per cent ground cover of snowgrass, herbs, shrubs, litter, bare ground, and of total ground cover.

The regression coefficients expressed as per cent increase in cover per year are listed in table 5. The significance levels for the regression coefficients, each tested against its own residual mean square, are also given.

### Results

LONG PLAIN

(i) Observations on relatively undamaged snowgrass areas excluded from grazing snowgrass that the cover contributed by snowgrass has varied inversely to the amount of cover contributed by herbs and litter.

(ii) On open snowgrass swards, showing initially 40–50 per cent ground cover, herbs and shrubs established quickly, providing from 10–30 per cent (mean 17.5 per cent) ground cover. Subsequent decreases in the amount of shrub has been compensated by increases in the amount of herb. Snowgrass cover has increased only very gradually and has varied from year to year.

(iii) Total ground cover (snowgrass and herbs + shrubs + litter) increased in the first three seasons by a mean value of 20 per cent and has shown only a 12 per cent increase in the subsequent eleven years.

KIANDRA

(i) Mean figures on undamaged snowgrass areas indicate that a stable ground cover in excess of 90 per cent has been maintained during fourteen years exclosure from grazing. A balance between snowgrass and inter-tussock herbs has been maintained.

(ii) On open snowgrass areas (60–70 per cent initial ground cover) there was:

(a) A decrease in snowgrass of 10 per cent over the initial four-year period attributable to plants unthrifty at the time of exclosure.

(b) An associated 7–8 per cent increase in the herb component in this period.

(c) In the ensuing period, snowgrass cover increased by 20 per cent and after 10 years exclosure, the commencement of a progressive improvement in total ground cover was seen.

(iii) On severely damaged snowgrass areas (0.20 per cent initial cover) there was:

(a) An increase in the total ground cover of up to 25 per cent in the first 4 years after exclosure, due to a considerable increase (15 per cent) in the herb component.

(b) On the areas where ground cover had been completely lost there was no recolonization in the first eleven years. Re-invasion, even then, was of minor importance and was due to *Acetosella vulgaris* Fourr., a naturalized rhizomatous perennial, capable of persisting on eroded and eroding surfaces.

PLAINS OF HEAVEN

(i) On closed snowgrass swards there has been a slow but progressive decrease in snowgrass cover. This has been largely offset by increases in per cent inter-tussock herbs.

(ii) Mean total ground cover on open snowgrass areas has shown a slight decrease, related in part only to the decrease since 1963 in the contribution of shrubs to the ground cover.

(iii) Site effects may explain the apparently anomalous situation as all "open" snowgrass tussock quadrats are located on shallower, drier, stonier sites than the closed sward quadrats.

**Discussion**

Not too much weight should be attached to the significance levels for the individual co-efficients quoted in table 5. The more important evidence is the trend in the rates of change in relation to initial values.

On all three sites, there has been an increase in the per cent cover of herbs in open ("damaged") snowgrass quadrats whereas on undamaged ("climax") closed sward quadrats, variations in per cent snowgrass cover and per cent herb cover are largely compensatory. This is the dynamic situation which one would expect in a "climax" vegetation community.

In climax vegetation, one would expect some readjustment in time of the total cover, and that for quadrats with 100 per cent initial cover there would be a regression towards the climax mean, and for those below the mean an upwards progression towards it.

For quadrats initially far removed from the climax cover, one would expect much larger ultimate increases towards the climax mean, but the time taken for the recovery process to get under way could depend very much on the initial cover and soil condition. The evidence of figure 6 suggests that over the 14 years of study the greatest recovery was made in quadrats with initial ground cover of the order of 50–60 per cent. This may well be related to the low survival rates of seedling regeneration on bare ground due to the intense frost heave effects experienced in spring and autumn.

Figure 7 gives the corresponding plot for snowgrass cover. The trend is much more poorly defined.

Within the climax vegetation (90–100 per cent ground cover) the trend is the regres-

TABLE 5

PER CENT COVER INCREASE/ANNUM

| Location | Quadrat | Init. S/G | S/G | Herbs | Shrubs | Litter | Total G.C. | Init. G.C. |
|---|---|---|---|---|---|---|---|---|
| *Undamaged—* | | | | | | | | |
| Plains of Heaven ... | Q1 | 80 | 0.44 | —0.45 | —0.04 | 0.11 | 0.05 | 90 |
| | Q2 | 95 | —0.21 | 0.28* | —0.04 | —0.03 | 0.00 | 100 |
| | Q3 | 100 | —0.78 | 0.05 | 0.00 | —0.50 | —1.23* | 100 |
| | Q4 | 90 | —1.98* | 0.89* | 0.00 | —0.14 | —1.24* | 95 |
| Kiandra ... | Q1 | 85 | 0.29 | —0.56 | —0.04 | —0.00 | —0.30 | 95 |
| | Q3 | 85 | —0.86 | 1.17 | 0.28 | —0.20 | 0.38* | 95 |
| | Q4 | 80 | 0.67* | —0.10 | 0.04 | —0.19 | 0.43* | 90 |
| | Q5 | 85 | —0.10 | 0.62 | 0.00 | —0.11 | 0.41 | 90 |
| Long Plain ... | Q4 | 95 | —1.43 | —0.50 | 0.00 | 1.62* | —0.31* | 100 |
| | Q5 | 95 | —1.52 | 0.23 | 0.00 | 1.08* | —0.20 | 100 |
| Plains of Heaven ... | Q5 | 20 | —1.80* | —1.24 | —0.30* | —1.33* | —1.06 | 90 |
| | Q6 | 75 | 0.05 | 0.24 | 0.00 | —0.81 | —0.52 | 85 |
| | Q8 | 40 | —0.66 | 2.01* | —2.05*** | —0.16 | —0.85 | 90 |
| Kiandra ... | Q6 | 0 | 0.05 | 0.23* | 0.00 | 0.00 | 0.28* | 0 |
| | Q8 | 15 | —0.07 | 0.38 | 0.01 | —0.29 | 0.03 | 20 |
| | Q9 | 60 | 1.13** | 0.50 | 0.00 | —0.07 | 1.56** | 65 |
| | Q10 | 60 | 0.85 | 0.06 | 0.00 | —0.13 | 0.78 | 65 |
| Long Plain ... | Q2 | 40 | 1.02 | 0.24 | 0.70* | 0.16 | 2.12** | 40 |
| | Q3 | 55 | 1.22 | 0.24 | 0.00 | 0.04 | 1.51** | 60 |

Significance:

* $P > 0.05$.
** $P > 0.01$.
*** $P > 0.001$.

sion line of current cover on initial cover (figure 6), the bivariate surface tending to zero correlation with increasing interval in time. The greatest absolute rate of increase in cover will probably be in the 60–70 per cent initial cover plots at the beginning of exclosure. Progressively with the time there will be a shift to the left so that finally (year "n") the greatest increase in later intervals will be on plots initially with little or no cover, provided the soil is not so severely eroded as to make recolonization impossible.

The degree of deterioration reported here appears to have been greater than those described for the Victorian Bogong High Plains (Carr and Turner, 1965b) where the exclusion of the grazing cattle led to a gradual improvement in the amount of vegetative cover on areas having reached an equilibrium under grazing of 5–20 per cent bare ground. The areas reported here are typical of much of the mountain grassland in the Snowy Mountains of New South Wales, below the treeline (about 6,400 feet) and after nearly a century of mixed sheep and cattle grazing with periodic burning, had deteriorated to 30–100 per cent bare ground.

Costin *et. al.*, (1960) in their study of surface run-off and soil loss in the Snowy Mountains, found run-off and soil loss to be significantly higher on an incomplete cover of snowgrass than on a natural closed ("climax") grassland. Soil loss increased from nil to 4.7 lb/50 sq ft (1.8 tons/acre to 58.6 lb/50 sq ft (22.8 tons/acre). The conclusion reached was that closed ("climax") grassland having herbs and herbaceous litter approaching 4 tons/acre was necessary for adequate soil protection.

In this context, one can consider further the implications of figure 6. Since in de-

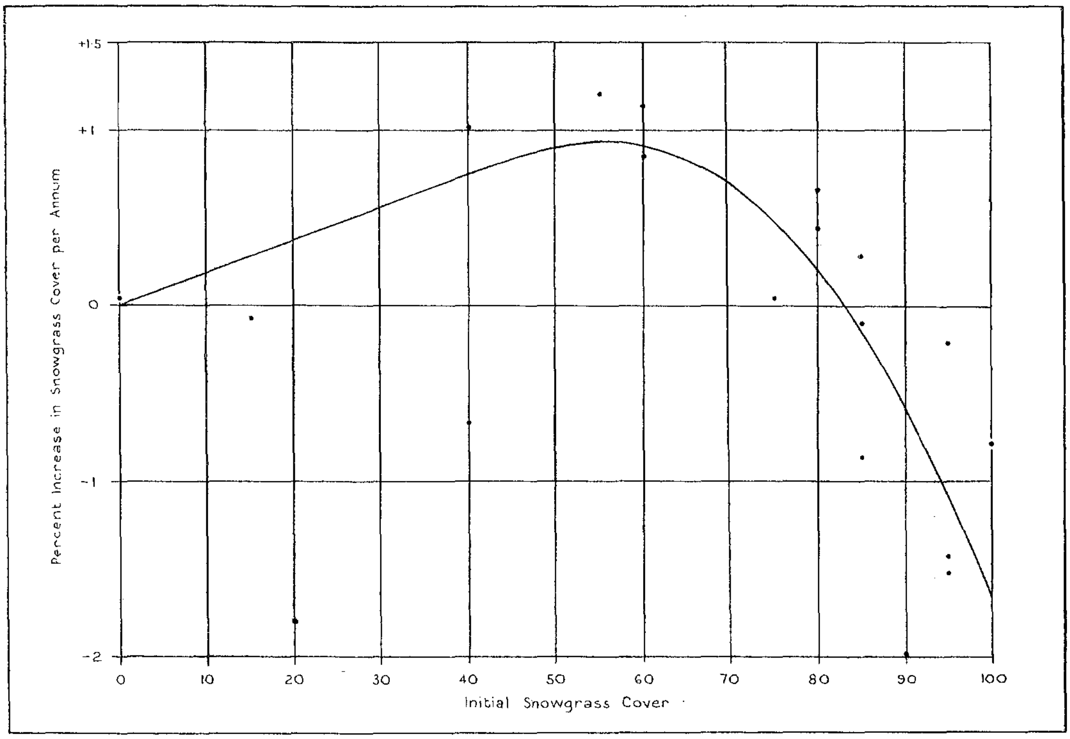


*Figure 7.*—Snow grass recovery rates over a fifteen-year period

teriorated communities similar to those here examined, one may observe accelerated erosion to occur, it is unlikely that the condition of reasonable soil stability to allow recolonization from near bare to near climax grassland cover in a period suggested as approaching 60–80 years, could be met in many situations.

Further, since it is apparent from historic comments reported in Costin (1954) and Bryant (1968 a, b,) that the opening of closed snowgrass swards is an induced condition, the advisability of grazing these areas under the presently accepted summer management system, is open to serious question.

## GENERAL DISCUSSION

Management of the high mountain catchments of the Snowy Mountains for the maintenance of high quality water yields is of primary importance to Australia. It is equally important to know the potential effects of the various catchment management systems being practised or proposed.

Costin *et al.*, (1959, 1960, 1961 a, b,) have studied the hydrology of parts of these mountains in some detail. They have found that most effective erosion control is provided by continuous herbaceous cover at a yield rate of about 4 tons/acre over dry weight but that where the cover is sclerophyllous, the yield rate for erosion control approaches 11 tons/acre oven-dry weight. For maximum interception and accumulation of snow, rain, fog, and cloud and the extension of the time of snow melt, these workers have found tree vegetation, preferably open stands or dense stands with small clearings to be the most satisfactory.

Costin (1958) considered that grazing in these mountains can be expected to reduce total ground cover by selective grazing of inter-tussock herbs, and to reduce both the vigour and cover provided by snowgrass be-cause of litter damage and uprooting. This partly provides a predisposing condition for shrub invasion. Associated burning further weakens and opens the ground storey vegetation, drastically reducing ground cover by litter destruction and encourages stock concentration upon deteriorated vegetation. This should be equated against the contentions reported by Newman (1954), Taylor (1956) that heavy grazing and/or regular burning-off is necessary,

(i) to prevent bushfires;

(ii) to control and replace such undesirable shrubs as hop bush and *Cassinia* spp., with snowgrass.

(iii) to remove unpalatable growth and stimulate fresh tussock growths;

and that fire and grazing do not damage the pre-existing "climax" vegetation.

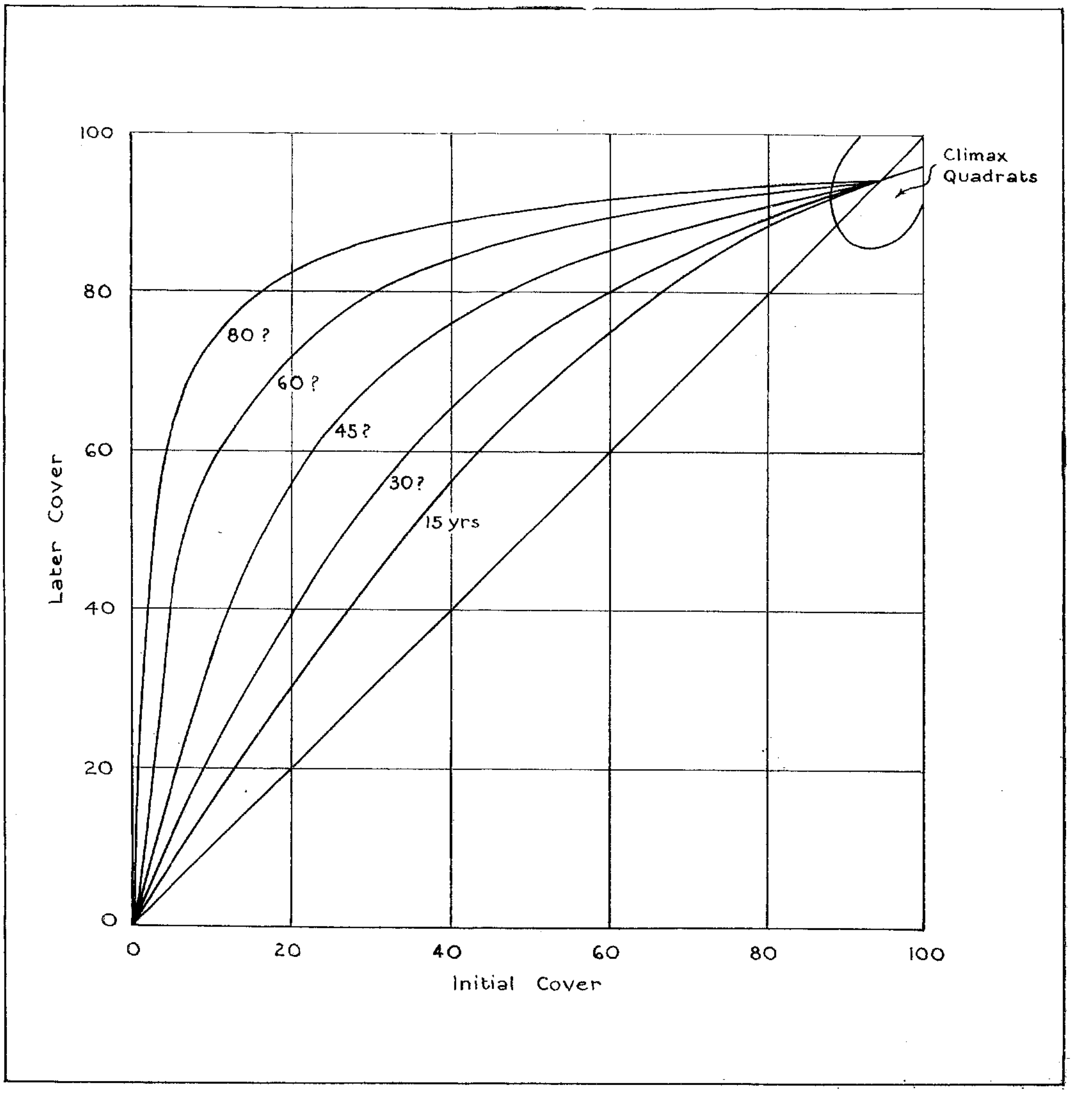


*Figure* 8.—Probable ground cover recovery patterns of deteriorated Snowgrass Tussock Grassland

The results presented elucidate several contentious matters.

The exclusion of grazing stock and the elimination of periodic control burning from a sub-alpine woodland community has increased the effective regeneration of snow-gum seedlings whereas continued grazing and burning suppresses seedling growth and therefore limits the life of the community by preventing tree replacement. It would be logical therefore to exclude even-aged mature woodlands from grazing periodically and by self-perpetuation, maintain the vigorous woodland community considered by Costin *et al* (1961a) as so valuable in optimum catchment management.

On relatively stone-free soils, protection from grazing and burning has not resulted in the forecast spectacular increases in shrubs. Rather the proportion of shrub has been related to the natural environment and to the degree of competition offered by herbaceous plants. The period before a return to predominantly herbaceous ground cover has varied but within 15 years consistent significant decreases in the shrub component had been measured.

The removal of grazing and its attendant management tool, the "controlled burn", as influences on snowgrass tussock grassland, was followed by increases in the herb component and in the total ground cover. Initially, herbs comprised only 0–9 per cent of the grassland sward. Within 3 to 5 years they comprised 15–20 per cent of the grassland sward. This confirms the controlling influence of grazing on the inter-tussock herb communities pointed to by Costin and his colleagues. It implies a significant stock concentration on the herb component—less than 10 per cent of the total cover. It parallels the situation measured in CSIRO grazing trials at Dainer's Gap where sheep graze snowgrass only after all herbs have been grazed (D. J. Wimbush, pers. comm.).

Further it is apparent that the opening of closed or climax grassland sward is an induced condition. When deterioration has taken place, the time for regeneration to the climax ground cover after exclosure varies with the amount of damage to the cover. As set out in figure 6, it may well exceed 80 years provided accelerated erosion does not completely prevent recolonization.

On the basis of results presented therefore, summer grazing and periodic burning cannot be said to be acceptable practices in the grasslands and woodlands of the Snowy Mountains between 4,000 feet and 6,000 feet where the primary objective is the maintenance of catchment values.

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