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TREND IN BARE GROUND FROM TUSSOCK GRASSLAND SURVEYS, CANTERBURY, NEW ZEALAND

Summary: Trend in the proportion of bare ground in some Canterbury tussock grasslands is analysed using records of vegetative cover from Fox Peak, South Opuha River (1963-1985); Porter River (1976-1984); Waimakariri Basin (1962-1978); and central Waimakariri River (1947-1981). The overall proportion of bare ground changed little in all four surveys. The lowest altitude site at Fox Peak and a low altitude plot in Porter River, showed a significant decrease in bare ground. Other plots and transects in Porter River and Fox Peak, and the Waimakariri Basin records showed no overall change. No significant trend was found for any of the central Waimakariri River transects, although some 20 m long segments of some transects show significant trends. The surveys suggest that there has been no overall increase or decrease in bare ground in the last 10-35 years, although vegetation composition has changed in some areas and significant decreases have occurred on some low altitude sites and significant increases on sites with more than 80% bare ground.

Keywords: Soil erosion, tussock grasslands, vegetation surveys, bare ground, Waimakariri River, South Opuha River, Porter River, Canterbury, mountain lands, trends.

Introduction

Bare ground is the non-vegetated, non-litter-covered part of the land surface. It includes scree, bare soil and subsoil, erosion pavement and exposed bedrock. In part it is a result of soil erosion, with frost action pulverising bared soil which is then blown or washed away. An increase in bare ground is likely to indicate an increase in soil erosion. The impact, cause, extent and changes in area of soil erosion in the South Island mountain land have been the subjects of considerable debate. In an early survey Gibbs *et al*. (1945) mapped severe soil erosion over most of the eastern high country in the Southern Alps. They considered the erosion was induced by pastoral mismanagement, and believed the area of bare ground was increasing. Repeat photography of pastoral land in the Porters Pass area, Canterbury, however, indicates that in the last 80-90 years the proportion of bare ground has not changed consistently at the four sites studied, suggesting that the impact of European pastoral management was not as great as early workers believed (Whitehouse, 1982). Recent workers have attempted to place the effect of early European management on erosion in perspective with natural erosion rates and the effect of deforestation following fires in the Polynesian era (O'Connor, 1984; Whitehouse, 1984; McSaveney and Whitehouse, 1988).

Since 1947 Catchment Authorities and some government departments have quantitatively assessed vegetative cover in tussock grasslands that are either extensively grazed or destocked. These surveys include measurements of the proportion of bare ground. Analysis of trend in the proportion of bare ground is possible from repeat surveys.

Dick (1978) indicated that bare ground increased from 1947 to 1963 on three vegetation transects in Broken River, Waimakariri Basin. However, more recent analysis of updated records from these and four other transects in central Waimakariri River Basin show no significant change in bare ground over the period 1947-1981 (Scott, Dick and Hunter, 1988), with a significant increase before 1953 on all transects balanced by a significant decrease since that time. In the Harper and Avoca River areas, Rose (1983) found no significant change in the proportion of bare ground on 26 transects surveyed in 1965, 1975 and 1980.

This paper presents an analysis of the bare-ground component of available, long-term, vegetation surveys in the Canterbury tussock grassland from Waimakariri River to the Two Thumb Range. These surveys monitor montane, subalpine and alpine, short and snow tussock grassland. None of the surveys are in areas modified, since or immediately prior to when the surveys were established, by pasture improvement or afforestation. Most sites are, or have been, grazed by sheep and/or wild animals. Some sites have been destocked. All sites, with the exception of perhaps a few in the upper Waimakariri River and Puketeraki Range, have not been burnt since the surveys were

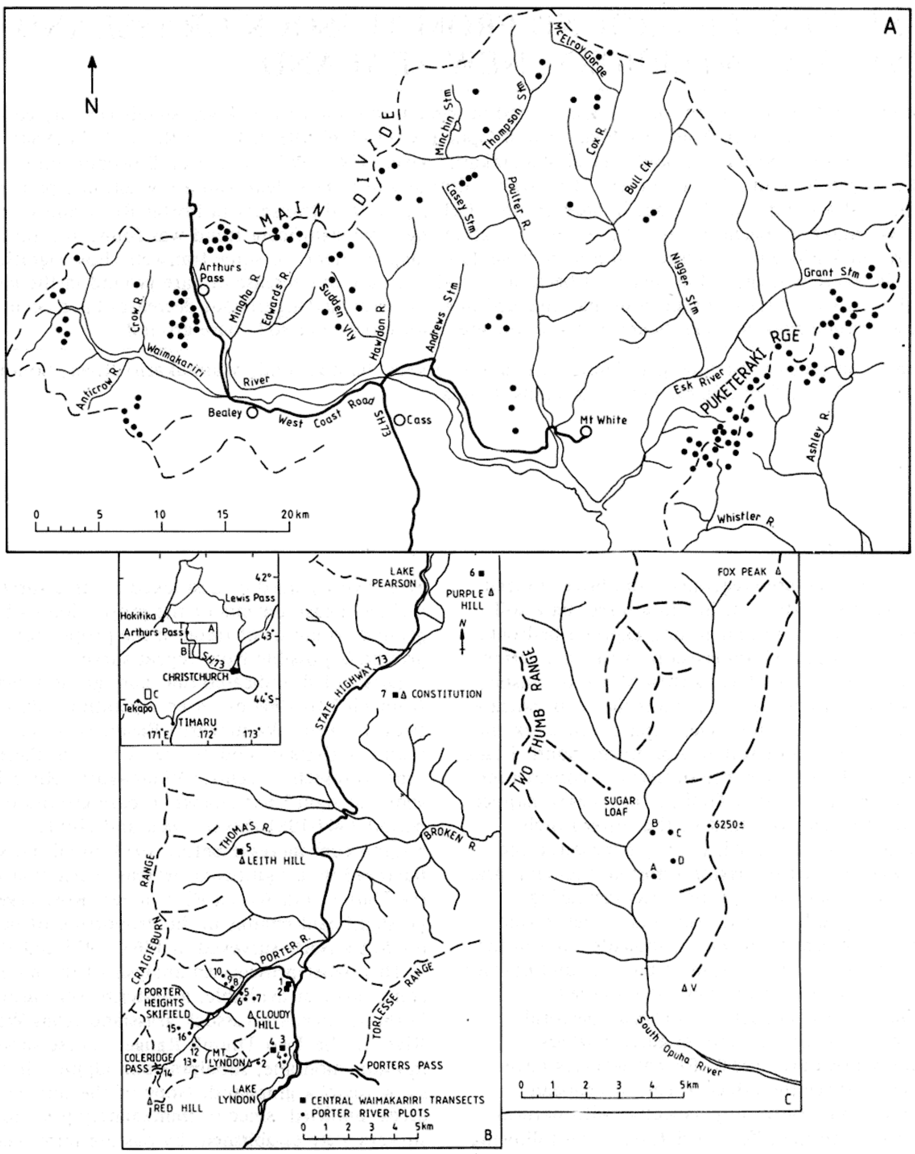

Figure 1: *Location of grassland transects and plots: Waimakariri Basin A; central Waimakariri River transects and Porter River plots B; Fox Peak transects* C. *Central Waimakariri River transects are numbered J: Cloudy Knoll middle;* 2: *Cloudy Knoll south;* 3: *Lyndon lower;* 4: *Lyndon upper;* 5: *Leith Hill;* 6: *Purple Hill;* 7: *Constitution Hill. Porter River plots are numbered as* in *Table* 2.

established. To facilitate comparison with the other surveys, the records of Scott *et al*. (1988) have been reanalysed. Changes in vegetation composition are beyond the scope of this paper although some qualitative comment is attempted. Vegetation changes are discussed by Scott *et al*. (1988) for the central Waimakariri River transects and by Rose (1983) for transects in the Harper-Avoca area.

The vegetation surveys

Fox Peak

In April 1963, vegetation transects were established by South Canterbury Catchment Board at four sites in the upper South Opuha River on an outlier ridge at the southeast end of the Two Thumb Range (Fig. 1). The transects are located on steep, west-facing slopes in the 1070 to 1460 m altitude range (Table 1). All four sites are within 1.3 km of each other. Mean annual precipitation ranges from about 2000 mm to about 2400 mm. The vegetation is dominantly *Chionochloa rigida* with herbs, adventive grasses and shrubs. Approximately half of the area sampled is bare ground. This is predominantly (60-80%) stone pavement. The area enclosing all transects was lightly grazed for about the first five years of monitoring, then destocked until the early 1980's. Since then, low numbers of sheep have grazed the area each year from about January until April.

At each site eight 30 m transects were established in a radiating pattern. On each, cover was assessed using the sampling method of Hercus (1962). This method samples every 0.6 m using a weighted 6.35 mm diameter ring. Transects were surveyed annually, in either April or May, from 1963 to 1985, except for 1968 and 1980. Site A was not surveyed in 1975 and 1976. The transects were repegged in 1969. At this time some old pegs were not found and these transects were relocated close to the original transects. In the analysis of bare ground, relocated transects are only analysed from the time of relocation. This reduces the period of observation for transects 7 and 8 at Site B and lines 5 to 8 at Site D to 1969-1985. With the exception of 1979, sampling has been carried out by just two different observers in the 16 year programme. The 1979 results have been omitted as this assessment of cover differs markedly from that of the observers in other years.

Porter River

Fourteen plots, each comprising eight stereo-photo points, were established in February 1976 in the Porter River Crown Land Management Area on the southwestern end of Craigieburn Range (Fig. 1). The plots were resurveyed in February 1984. They sample a variety of slopes from 880 to 1370 m altitude (Table 2). Mean annual precipitation is about 1200 mm. The vegetation is dominantly depleted snow-tussock grassland *(Chionochloa macra)* with adventive grasses, *Dracophyllum* scrub and *Celmisia* spp. Bared subsoil, scree and stone pavement make up the bare ground in the area. The area was destocked in 1974 and the plots established on representative sites to monitor vegetation change.

The survey method followed that developed by the Forest Research Institute for tussock grasslands (Allen, Rose and Evans, 1983). For the purpose of the present analysis percent 'bare ground' is the sum of rock and bare-ground components recorded on the 100 points placed over the projected transparencies.

Waimakariri Basin

Transects were established by Forest Research Institute at 185 sites in the subalpine tussock grasslands of

Table 1: *South Canterbury Catchment Board transects at Fox Peak. South Opuha River. A.verage area of bare ground is calculated from records from all years. **indicates trend in proportion of bare ground significant at 0.01 level using. Spearman rank order statistic.*

Location	Grid reference	Altitude (m)	Slope (°)	Aspect	Vegetation	Bare ground (%)	Trend
Site A	S90 323095	1070	34	W	Snowgrass and cotton plant with *Hieracium* spp. and adventive grasses	17	decrease**
Site B	S90 323109	1250	36	W	Snowgrass. cotton plant. herbs and adventive grasses	42	no change
Site C	S90 328190	1460	26	W	Snowgrass, cotton plant with blue tussock and adventive grasses	32	no change
Site D	S90 329100	1370	36	NW	Snowgrass. cotton plant with blue tussock and adventive grasses	36	no change

Table 2: *Porter River Crown Land Management Area vegetation plots. Plots* 3 *and 11 of the survey are not included* in *this analysis. Bare ground percentage is the average from a*// 8 *stereo-pairs for both years. **indicates trend* in *proportion of bare ground significant at 0.01 level using Mann-Whitney test.*

Location	Grid Reference	Altitude (m)	Slope (°)	Aspect	Vegetation	Bare ground	Trend
1 Lake Lyndon	S74 178853	1 000	24	ESE	*Dracophyllum* scrub	1	no change
2 Mt Lyndon	S74 167856	1 370	26	ENE	Sparse snow tussock	43	no change
4 Lake Lyndon	S74 180856	900	31	NE	Adventive grasses	2	decrease**
5 Cloudy Hill	S74 160888	880	20	W	Adventive grasses with matagouri and *Hieracium* spp.	21	no change
6 Cloudy Hill 2	S74 162886	1 000	30	NW	Adventive grasses with *Hieracium* spp	9	no change
7 Cloudy Hill upper	S74 166886	1 180	30	N	Snow tussock and adventive grasses	21	no change
8 South slopes 1	S74 156893	880	3	-	*Dracophyllum* scrub and hard tussock	5	no change
9 South slopes 2	S74 152897	975	12	SSE	Snow tussock and *Dracophyllum* scrub	45	no change
10 South slopes 3	S74 149899	1 215	24	ESE	Snow tussock with *Dracophyllum* scrub and *Celmissia* spp.	38	no change
12 Scree Ck ridge 1	S74 137864	1 030	21	NNW	Depleted snow tussock	65	no change
13 Scree Ck ridge 2	S74 138857	1 150	28	NW	Sparse *Dracophyllum* and snow tussock	69	no change
14 Coleridge Pass	S74 120851	1 130	10	N	Snow tussock and *Dracophyllum* scrub	0	no change
15 Ski road	S74 131873	1 280	28	ESE	Snow tussock	28	no change
16 Lower slopes	S74 135869	1 000	17	E	Snow tussock and *Dracophyllum* scrub	35	no change

Waimakariri Basin in 1962 (Wraight, 1966). The sites were established to monitor changes in vegetation following wild-animal control and were selected to representatively sample major plant communities. Animal numbers were high until the late 1950's, but had been reduced by 1962, and were very low by 1970.

Twenty-seven of the transects were resurveyed in 1972 (McLennan, 1974) and a further 113 resurveyed in 1978 (Fig. 1). The transects cover a wide geographical area and sample from 1050 to 1780 m altitude. Most are between 1300 and 1600 m altitude. Mean annual precipitation ranges from about 1700 to over 8000 mm. Vegetation is predominantly snow tussock grassland *(Chionochloa macra* and C. *pallens),* with some herbs and short tussock. The proportion of bare ground is highly variable and is predominantly stone pavement with stones overlying subsoil. Information on the location, altitude, aspect, vegetation, precipitation and estimated bare ground of these transects is summarised in Whitehouse and Evans (1986). Most have been extensively grazed by sheep, with grazing pressure greatest in the Puketeraki Range and Mt. Binser area.

Each transect is 40 m long, with cover recorded at the centre of a 15 cm ring every 40 cm (Allen *et al,* 1983). The total count of bare ground, including scree, stone pavement and rock, from the 100 records is taken as a measure of the proportion of bare ground for the plot. Some plots straddled boundaries between vegetation communities, with SO records for example, in *Chionochloa pallens* grassland, and the other 50 in *C. oreophila* grassland. For analysis of bare ground, these transects have been treated as two independent transects.

Central Waimakariri River

In 1947, transects were established by the North Canterbury Catchment Board in the central Waimakariri River to monitor the effects of grazing on the tussock grasslands. Seven of these 200-300 m long transects have not since been modified by burning, pasture improvement or afforestation. Data from these seven are analysed (Fig. 1). Scott *et al.* (1988) provide detailed description of the transects. The transects are located in large grazing blocks on four properties and sample steep slopes from 780 to 1300 m altitude.

On most transects, stock numbers have progressively decreased since the 1930's. Vegetation is short tussock grassland, dominated by *Festuca novae-*

zelandiae below about 950 m altitude, and snow tussock grasslands, dominated by *Chionochloa macra* and *C. flavescens,* above this altitude. Cover is generally sparse, with greater than 60070 bare ground on six of the transects. The bare ground on the transects predominantly comprises fine-textured subsoils or gravels thinly overlying finer materials (Scott *et al.,* 1988). Screes, boulder fields and rock outcrops are not widely represented.

The transects were surveyed annually, in either January or February, from 1947 to 1963 and again in 1980 and 1981. Vegetation cover was sampled using the point sampling method of Levy and Madden (1933), and is outlined is Scott *et al.* (1988).

Statistical analysis

Trend in percentage bare ground was investigated using nonparametric tests. For the data from the transects at Fox Peak and central Waimakariri River, where there are a series of measurements, the Spearman rank-order correlation coefficient (Lehmann, 1975) was used to test for trend. For each transect or transect segment, the bare ground measurements over time were ranked and correlation calculated between these and the rankings of the years of observations.

The records from the central Waimakariri River transects were divided into 20 m (1 chain) segments. This gave 10 or 15 records for each transect for each year. Trend was assessed for individual segements, and for the group of all segements in each transect. In addition, the segments were grouped by altitude and by percent bare ground, and analysed for trend. For the Fox Peak records, trend was assessed for each line and for the combination of the eight lines at each site. For the data from Porter River and Waimakariri Basin, where there are just two sets of observations, the Mann-Whitney test (Seigel, 1956) was used to investigate trend. The test does not indicate the magnitude of the trend. For the Porter River records, the eight measurements of percentage bare ground from the stereo photographs in 1976 and in 1984 were compared for each plot.

For the Waimakariri Basin records, the 1962 and associated 1972 and 1978 observations were compared using the Mann-Whitney test, for the entire 140 transects and for a wide variety of subsets of the data including transects grouped by area, including the Puketeraki Range transects and many subcatchments, by annual rainfall, by year of survey, by altitude and by proportion of bare ground (Whitehouse and Evans, 1986).

Results

Fox Peak

At Site A, the lowest altitude site, there has been a significant ($p<0.01$) decrease in bare ground in the period 1963 to 1985. All eight transects at this site show decreases over this period. The decrease is associated with an increase in *Hieracium* spp. and adventive grasses. At the other sites there is no overall change in bare ground, although significant change occurred on some individual transects. All sites show considerable annual variation in bare ground (Fig. 2). This variation is consistent between sites.

Porter River

For all of the plots, except plot 4, there was no significant change in the proportion of bare ground between 1976 and 1984 (Table 2). Plot 4 showed significant ($p<0.01$) decrease in bare ground associated with an increase in adventive grasses. The magnitude of the change is very small, decreasing from an average of 4.6% bare ground for the eight photo-points in 1976 to no bare ground in 1984.

Waimakariri Basin

No significant difference was found when testing pairs of observations from all 140 plots or pairs grouped by area and subcatchments, 'by altitude (greater than 1370 m), by proportion of bare ground (greater than 50% and less than 50%), or by annual rainfall (less than 2500 mm and greater than 2500 mm).

Central Waimakariri River Transects

The trend test showed no significant change in the proportion of bare ground on any of the complete transects over the period 1947 to 1981. Twenty-one of the individual (20 m long) segments showed significant increases while 16 showed significant decreases in bare ground (Table 3). All sites show considerable annual variation in bare ground;

Discussion

Annual variation

The measurements made by the South Canterbury Catchment Board of the transects at Fox Peak provide an excellent record of the annual variation in bare ground from 1963 to the present (Fig. 2). They probably reflect climatic variations. Scott *et al.* (1988) indicate that on the central Waimakariri transects,

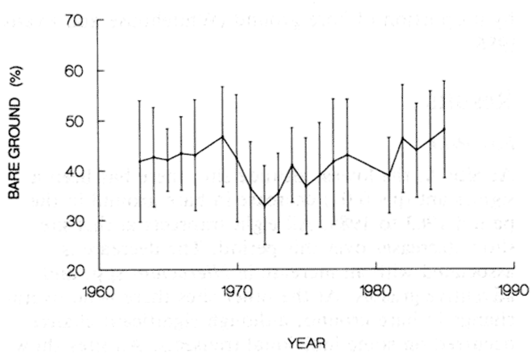

Figure 2: *Variation in the percentage of bare ground at Site B, Fox's Peak. Bars represent one standard deviation about the average of the six transects at the site that were not relocated in 1969.*

bare ground increased in years of higher-than-normal temperature and vegetation increased in years of higher-than-normal rainfall.

Such variations may make trends difficult to observe and this is especially true when surveys are repeated infrequently, as in the Porter River and Waimakariri Basin surveys. It is possible for such studies to show false trends when the observations correspond to below-average then above-average fluctuations, or *vice-versa*.

The records from Fox Peak highlight the local variability in vegetation cover. Variability between transects at the same site is greater than annual variation between transects (Fig. 2)

Central Waimakariri River transects

Scott *et al*. (1988) also analysed the bare ground data from the seven transects in the central Waimakariri River. Their results do not differ from the results in this paper. Scott *et al*. indicate that trend in vegetation cover is related to altitude and the proportion of bare ground on transects. They suggest that the proportion of bare ground increased at higher altitudes and decreased at lower altitudes in the study period, and show that significant increases in living vegetation occurred on already well-vegetated samples, and decreases occurred on sparsely-vegetated samples. To examine these same influences, the data for the eighty five 20 m segments were also analysed for the following groups:

(1) Segments with mean (1947 to 1981) bare ground less than 20% (16 segments); less than 50% (40 segments); greater than 50% (45 segments); and greater than 80% (11 segments).
(2) Segments from 780-950 m altitude (Cloudy Knoll middle and south, 25 segments); from 1120-1300 m (Lyndon lower and most of Constitution, 25 segments); and from H20-1300 m (Lyndon upper, Leith Hill, Purple Hill and part of Constitution, 40 segments).

The groups of segments with average bare-ground proportion of less than 20% and less than 50% show no significant trend over the study period, although in the latter group, 12 segments individually show siguificant decrease in bare ground and only two show an increase. Similarly, the group of segments with average bare-ground area greater than 50% show no significant trend, although 19 segments show significant increases in bare ground and only four show significant decreases. The group of segments with average bare ground of more than 80% likewise does not show a significant increase in bare ground at the 5% level, using non-parametric tests (cf Scott *et al*. 1988).

None of the altitudinally divided groups of segments show a trend in bare ground, despite 14 of the individual segments in the highest altitudinal group (1120-1300 m) showing a significant increase in bare ground and only four of the segments a significant decrease (Table 3). This result is similar to that of Scott *et al*. (1988). While they suggest that the. 'proportion of bare ground increased on the 'three highest altitude transects and decreased on the two lowest, they found no significant relationship between changes in bare ground cover and altitude when transects were subdivided into 100 m altitudinal classes.

Vegetation change

The absence of trend in the proportion of bare ground does not imply that no change has occurred in vegetation. Scott *et al*. (1988) show that *Festuca novae-zealandiae* has decreased consistently on most of the central Waimakariri River transects, and that *Hieracium* spp. and *Leptospermum scoparium* increased onsome of the transects. These changes are in general accord with the changes determined in the lower Avoca River by Rose (1983). Vegetation changes at Fox Peak and Porter River have not been analysed, but appear minor, although adventive grasses and *Hieracium* spp. have increased, particularly at low altitudes. The Waimakariri Basin plots record an

Table 3: *Segments (20m) of central Waimakariri River transects showing significant changes in the proportion of bare ground. Comparison of the average proportion of bare ground for the first and last five measurements provides an indication of the magnitude of change. ** indicates trend in proportion of bare ground significant at the 0.01 level, * at 0.05 level and †at 0.10 level using the Spearman rank order correlation coefficient.*

Location	Altitude (m)	Proportion of bare ground First 5 (%)	Last 5 (%)	Trend
Cloudy Knoll south	780-790	11	7	decrease**
Cloudy Knoll south	790-800	19	9	decrease**
Cloudy Knoll middle	790-800	10	6	decrease**
Cloudy Knoll middle	800-810	17	11	decrease*
Cloudy Knoll south	800-810	14	9	decrease*
Cloudy Knoll south	830-840	80	86	increase**
Cloudy Knoll south	840-850	99	100	increase*
Cloudy Knoll south	850-860	54	57	increase*
Cloudy Knoll middle	850-860	52	67	increase*
Cloudy Knoll south	860-870	77	73	decrease*
Cloudy Knoll middle	890-900	94	97	increase*
Cloudy Knoll middle	910-920	23	34	increase**
Cloudy Knoll middle	920-930	66	74	increase*
Lyndon lower	970-980	17	14	decrease†
Constitution	1020-1030	35	39	decrease*
Lyndon lower	1020-1030	14	8	decrease**
Lyndon lower	1030-1040	16	9	decrease**
Constitution	1040-1050	48	36	decrease**
Constitution	1090-1100	31	23	decrease**
Purple Hill	1140-1150	62	56	decrease*
Purple Hill	1150-1160	57	69	increase*
Constitution	1150-1160	55	61	increase*
Constitution	1160-1170	72	79	increase**
Purple Hill	1160-1170	52	57	increase*
Constitution	1170-1180	50	60	increase**
Lyndon upper	1180-1190	64	82	increase**
Lyndon upper	1190-1200	83	77	decrease*
Purple Hill	1200-1210	41	51	increase*
Purple Hill	1210-1220	64	68	increase*
Leith Hill	1220-1230	79	82	increase†
Leith Hill	1230-1240	72	81	increase†
Leith Hill	1240-1250	54	47	decrease†
Purple Hill	1250-1260	73	80	Increase*
Purple Hill	1260-1270	83	86	Increase*
Leith Hill	1260-1270	38	29	decrease**
Purple Hill	1270-1280	81	91	increase**.
Purple Hill	1280-1290	83	97	increase**

increase in tussock stature between 1962 and 1972 or 1978, although there was no major increase of seedlings and changes in species composition were generally minor. Previous workers have interpreted the changes in stature and species compostition as an improvement in 'watershed conditions' (e.g. McLennan, 1974) although the overall area of bare ground has not changed.

Conclusion

Analysis of bare ground in vegetation surveys of four areas in the Canterbury mountain lands indicate a lack of an overall significant trend in the proportion of bare ground in the last 10-35 years, although significant increases and decreases have occurred locally and year-by-year.

Acknowledgements

We are indebted to the foresight of earlier workers for establishing the plots and to the many people who recorded the vegetation. Earlier analysis by Graeme Barron and Grant Hunter ensured that the records from the central Waimakariri river transects were in a very manageable form. Tony Davoren helped with statistical software. Critical comments from Grant Hunter, David Scott, Mauri McSaveney, Allan Nordmeyer, Allan Rose, Noel Trustrum and an anonymous reviewer are appreciated.

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