TUSSOCK GRASSLANDS AND MOUNTAIN
LANDS OF NEW ZEALAND

Some Impressions of a visit to parts of the South Island,

June, 1962

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FOREWORD

In June, 1962, Mr A. B. Costin, of the Division of Plant Industry of the Commonwealth Scientific and Industrial Research Organisation, Australia, an ecologist of international repute, was invited to New Zealand by the Committee of Management of the Institute. Mr Costin has worked for many years in the Australian mountain country, especially in the catchment of the Snowy River. He was asked to inspect representative areas of the tussock grasslands and mountain lands of the South Island in the light of the objects of the Institute as defined by Cabinet:

"a. To investigate the various aspects of management of the tussock grasslands and mountain lands.

"b. To develop techniques to bring about a more protective and stabilising cover of vegetation, so as to mitigate soil erosion, and the choking of river channels with detritus, to minimise flooding, and to safeguard production.

"c. To provide a centre to facilitate the co-ordination of all research aimed to protect and improve the tussock grasslands and mountain lands, and to make this information readily available to all interested people and organisations.

"d. To foster and undertake research where necessary in any appropriate fields not otherwise covered."

Mr Costin has recorded his impressions in the following paper which is being sent to all those on the mailing list of the Institute. It should be stressed that the impressions are those of Mr Costin. While the Institute may not necessarily concur with the views expressed, it considers the matters raised are so important that they should be widely circulated among those who live and work in the tussock grasslands and mountain lands.

The Institute would welcome comment on matters raised and views expressed in the paper.

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INTRODUCTION

In June, 1962, at the invitation of the Tussock Grasslands and Mountain Lands Institute of New Zealand, I inspected parts of the South Island (Appendix 1), to make comparisons between high mountain areas of Australia and tussock grassland and mountain areas of New Zealand (Appendix 2) and thereby gain a clearer understanding of New Zealand problems. The inspections were arranged and conducted by the Director of the Institute, Mr L. W. McCaskill, usually in conjunction with other workers, runholders and administrators concerned with high country problems. Despite the necessarily selective nature of the visit, both as regards places and people, a reasonable cross-section of country, problems and opinions was encountered which, with recollections of an earlier visit in 1951, permitted some impressions to be formed.

What is the solution to the deteriorated condition of New Zealand tussock grasslands and mountain lands, as manifest in many ways such as soil erosion, stream aggradation, flooding, weed and pest invasion, and declining stock-carrying capacity? Since there is a common denominator to most of these areas—tussock grassland—a universal solution is sometimes expected. But the environment is so diverse, especially as regards topography, altitude and associated climate, that no one solution can be possible and the illusion is best forgotten. There are many problems and each may require a separate solution.

There is little point is discussing the many day-to-day problems with which New Zealand workers are already fully familiar, such as the need for cheaper effective fencing, and feral animal and weed control. The basic question is the determination of correct land use and this is the issue which is considered here.

DISCUSSION

The underlying need is a detailed resources inventory in which the natural land systems in terms of climate, land form, geology, hydrology, soils, fauna and vegetation are defined and mapped. Basic land use capability plans for all important catchments can then be prepared. New Zealand workers are already familiar with this approach on a farm and small catchment scale and in fact are emerging as one of the world leaders in this field. Basic resource inventories also help to define more local problems such as the location of flood and sediment source areas, and to suggest measures for their control.

Long range forecasting of local needs and overseas trade prospects should also guide land use decisions. Despite the uncertainties of long-term prospects, it seems reasonably clear that New Zealand will continue to rely heavily on the overall suitability of its environment to produce plant and animal products and that in an increasingly food-hungry world these will always be in demand. The New Zealand environment is particularly favourable for forest growth, if exotic species such as Monterey and lodgepole pines and eucalypts are used as standards rather than the indigenous species, and with the advance of wood technology, it is likely that almost any form of cellulose, regardless of quality, will be usable, perhaps even for human food. Sooner or later, the tremendous electric potential of New Zealand's mountain lakes and rivers will be evaluated and developed. Local irrigation in subhumid and semi-arid areas will also increase. Another fairly certain forecast is that the recreational potential of New Zealand mountain areas will be increasingly recognised and developed as an important source of income from overseas visitors.

Although each catchment presents its own peculiarities, most of them can be subdivided broadly into lower fan and valley situations and adjacent gentle slopes; steep lower and middle slopes up to the bush limit at 3000 plus or minus 500 feet; and steep upper slopes and mountain tops above this level. In the light of present knowledge and probable trends (cf. Appendices 1 and 2), the following generalisations can be made:

The valleys, fans and adjacent gentle slopes which can be cultivated at least to the extent of sod-seeding are suitable for more intensive pasture development. In many cases (e.g.,the Mackenzie Basin) there are soil nutritional problems but these are soluble and and much higher production, probably with local irrigation, can be expected in future years.

The steeper, lower and middle slopes up to the bush limits are also capable of growing improved pasture species: for example, white and red clovers, ryegrass and cocksfoot can be established and maintained by oversowing and topdressing. However, as this is potentially a forest environment in which woody plants either trees or shrubs will be establishing themselves vigorously, and because of the highly selective grazing habits of livestock in such areas, grazing will always remain relatively inefficient. On a variety of grounds, forests probably make more efficient production. Their foliage intercepts the maximum amount of sunlight and their deeper rooting habit enables them to draw on larger reserves of soil moisture and nutrients than shallow rooted pasture plants. Arboreta throughout the South Island are showing that a variety of economically valuable conifers can grow well.

On the steep upper slopes and mountain tops above the bush limit where any kind of plant establishment is slow, the native tussock and herbfield cover will always be important. Although today treeless parts of the 3,000-4,000 foot belt may also be suitable for some form of tree growth.

The next step is to examine how the actual and possible vegetation types (e.g., tussock grassland, improved pastures, beech and conifer forest) affect hydrological values in terms of flood control, hydro-electric development, and irrigation in that priority. Although the investigations necessary to make this assessment have not yet been carried out under New Zealand conditions, certain general relationships can be accepted.

For flood control,* the plant cover should promote maximum infiltration, minimise soil loss, and have the highest possible evapotranspiration (i.e., minimum water yield). Hydro-electric and irrigation development also have the first two requirements but with full development they require minimum water use from the plant cover (i.e., maximum water yield). However, New Zealand has such abundant water resources that the requirements of flood control are likely to remain foremost. The relevant properties of plants for these purposes are as follows.

For maximum infiltration the surface area of plant material exposed near ground level is a critical factor. The larger the surface area of foliage and litter the more moisture is intercepted and detained, thus providing maximum opportunity for it to soak into the soil. Weight for weight, therefore, fine-leaved species such as grasses are more effective than crop plants, and a large bulk of ungrazed and unburnt plant material will promote greater infiltration than a burnt or short-grazed pasture. The effectiveness of shrubs and trees depends on the type and amount of leaf litter they produce. Weight for weight, fine-leaved litter should be more effective than litter from broad-leaved species.

The high infiltration which results from adequate ground cover also helps minimise soil loss. On slopes exceeding 25 to 30 degrees, and on soil materials disposed to mass movement, root development is also important; the deeper the root development, as with trees and native tussock grasses, the more stable the soil mantle is likely to be.

A large bulk of fine-leaved, deep-rooted vegetation will therefore make a considerable contribution to flood control by delaying run-off and producing clean water, and consequently minimising river erosion and aggradation and flooding downstream. It will also reduce flood peaks, and in environments where potential evapotranspiration exceeds precipitation for part of the year, the actual volume of flood water will be reduced. In subhumid and semi-arid environments a plant cover with active roots down to four feet could absorb and retain up to a foot more rainfall than a purely surface-rooting cover. In the wetter areas where the soil is never far from field capacity, root depth will be less important.

The colour of the vegetation is likely to have an effect on water

* The importance of downstream engineering works is also recognised but lies beyond the scope of this report.

use, soil moisture content and volume of discharge, both in humid and drier areas. The lighter the colour of the foliage the more sunlight will be reflected and the less will be available for water use. The dark-leaved canopies of most conifers and mountain beech absorb most of the incoming energy and hence should transpire more. In this respect, the contrast between tussock and forest-covered slopes is marked; on the basis of probable differences in albedo* values water use by forest could be 10 to 15 per cent greater than that of tussock grassland. Differences of this order could result in up to five inches more water use by forest per year on sunny slopes. On shady slopes, the differences in water use would be less.

Thus, the combined effects of a deep root system and dark foliage could result in more than 12 inches more water use by forest than by grassland in subhumid and semi-arid areas, and up to six inches more in humid environments.

The current emphasis on extending the range of recognised pasture plants, especially white clover, into higher and higher areas may not therefore be in the best interests of flood control. As a first step in land reclamation it can be important, provided the bare areas are occupied, but the limited data available suggest that the clover establishes mainly within existing plants, some of which are subsequently eliminated. As in Australia, it is likely that the plant cover which gives the best grazing is different from that which gives most effective catchment protection and flood control. Detailed measurements of infiltration, soil loss and water use of different types of cover in different mountain environments of New Zealand are urgently needed to examine these important questions.

Australian experience suggests that above 3,000 feet in New Zealand where tree growth will always be difficult, a tall, rank-growing tussock cover will be found most suitable for catchment purposes, but it will have little value for grazing. The establishment of trees in eroded areas up to 4,000 feet would be desirable on flood protection grounds, but it would depend on introducing suitable species from overseas. Lodgepole pine (*Pinus contorta*), the most promising species to date, warrants further trials despite the fear it might become still another weed.

The steeper lands below 3,000 feet are basically forest environments, and forestry for catchment protection, possibly with some timber production, is the most suitable use. It would, of course, take many years and huge resources to carry such a project to completion. A more realistic approach might involve rigid protection of existing areas of natural forest, with encouragement of regeneration through fire control and effective reduction of grazing pressures. More research is needed into problems of secondary succession of beech forest, for example the role of "weed" species such as sweet brier and matagouri as cover crops for beech establishment. Elsewhere, re-afforestation should be based on vigorous exotics, concentrating first on the steep eroded sunny faces since it is here that beneficial effects of trees on flood mitigation are likely to be greatest. Because of practical, economic and social problems, complete afforestation of

* Albedo-Ratio which the light reflected from an unpolished surface bears to the total light falling on it. Angstom gives values of 0.26 for grass and 0.14 for pine. Potential evapotranspiration would therefore be greater from pine forest than from grassland, according to these figures.

steep mountain lands below 3,000 feet may not be realised, but a satisfactory compromise may be worked out. In view of the fact that steep slopes will be grazed only over a fraction of the total area, and weed problems (from the grazing point of view) will always remain, it would be preferable to confine grazing to relatively accessible areas where the problems of weed and pest control, seeding and topdressing can be easily handled. The rabbit problem in tussock grassland has probably arisen because grazing disturbance has created a favourable habitat, and the most effective permanent control may well be to provide a cover—e.g., a forest or snow tussock grassland—which is unsuitable for rabbits. Such a cover would have little grazing value but it would be suitable for flood control. Thus, those runs consisting almost exclusively of steep hill country would be gradually withdrawn from grazing and developed as forests, while grazing would be retained where there is adequate valley, fan and gentler sloping land for improvement as a joint catchment-grazing proposition; some amalgamation of runs would probably be required. Experience at Molesworth and Mid-Dome indicates that such a successful catchment-grazing compromise may be possible, especially if the principle is accepted that livestock should be used as an economic means of catchment improvement rather than as an end in themselves. Thus, cattle are preferable to sheep since they permit a coarser herbaceous cover (e.g. of cocksfoot) more suitable for flood control to be maintained. Another advantage of cattle is that they are a more sensitive indicator of the state of the catchment than sheep, since they lose condition more easily and thus give obvious warning that cover is being depleted to dangerous levels.

CONCLUSIONS

Subject to confirmation by the hydrological investigations recommended, it is therefore proposed that:

1. The basins, valleys and fans should be developed intensively for grazing purposes, either on a year-round basis or for summer grazing in association with winter agistment to lower pastures. Local irrigation, for example in the Mackenzie Basin, could increase production from these areas.

2. From the long-term point of view the steep slopes up to the bushline at about 3,000 feet should be regarded primarily as forest sites, where management is for flood control, with limited timber production. The protection and regeneration of existing forests of mountain beech should be carried out wherever possible with large-scale afforestation with conifers on depleted tussock country. Eroded sunny aspects should be regenerated first, since it is here that the beneficial effects of forests on flood mitigation will be greatest. Stable and regenerating areas of snow tussock should be retained. Grazing, preferably by cattle, would then be confined to the gentler slopes adjacent to the valleys at intensities which would maintain a dense, rather coarse, deep-rooted cover (e.g. of cocksfoot).

3. Above the bushline the management objective should be a dense, tall-growing tussock cover, and on eroded areas up to 4,000 feet reclamation by tree species such as lodgepole pine should also be attempted. Since this kind of cover is not attractive to livestock unless disturbed, there seems to be no future for grazing at these higher levels.

APPENDIX 1—NOTES ON INSPECTIONS

Christchurch—"Inverary"—Ashburton Gorge

This inspection served as a reminder of the huge contrasts in New Zealand due to topography, in this instance between the almost flat, highly improved and intensively utilised Canterbury Plains and the steep, deteriorated, sparsely grazed tussock grasslands and mountain lands. There is virtually no intermediate foothill country, as in Australia. On the other hand, large valleys such as the Ashburton run almost to the backbone of the Southern Alps, providing gentler slopes on which there is some opportunity for a minor, modified Canterbury Plains-type of development. The homestead paddocks of "Inverary" have been improved in this way to provide some winter feed and thereby somewhat reduce the high winter grazing pressure on the steeper sunny surfaces. Some good examples of pasture improvement following rabbit control and aerial oversowing were also seen on lower hill areas around "Inverary" itself.

The importance of aspect in determining broad patterns of livestock distribution, especially in winter, was obvious along the Ashburton Valley. Most of the sheep seen were on the sunny faces and at this time of the year (early winter) the cold shady faces were virtually ignored. The juxtaposition of various types and degrees of vegetative cover from thick snow tussock, fescue tussock with clover and other minor herbs, to more or less open ground and large bare "guts" was also evident. High fencing costs and low per acre returns render subdivision and separate management according to slope and cover classes unpractical.

Even allowing for the fact that much of the tussock country up to 3,000 feet once carried forests of mountain beech, either in Maori or white man's time, the native vegetation is remarkably uniform as regards structure and dominants. Despite the marked differences in topography and elevation already mentioned, and the consequent diversity of climatic and soil conditions, snow tussock grassland or communities derived from it are the predominant cover. This predominance must encourage the view that a wide variety of situations can be managed in the same way simply because the plant communities are (or were) the same. Admittedly, this pattern has been complicated by invasion of fescue tussock and naturalised herbs and weeds and by the development of bare areas, but the over-all impression of vegetative uniformity remains in an environment which in other respects is highly complex.

Rakaia Catchment—Lake Coleridge and Lyndon Area

The Rakaia Valley upstream from the Gorge provides further examples of the contrast between valley and mountain environments, with scope for more intensive pasture development and subsidiary cropping along the valley and on adjacent fans. Near Lakes Coleridge and Lyndon many active guts are in evidence. The remarkable feature of these mass-movement effects is their large size compared with the small area of catchment. Few catchments in the world have higher sediment/catchment area ratios. There is obviously a very high erosion hazard, regardless of the relative contribution from natural and human agencies.

Broken River Catchment

The Broken River catchment provided some interesting contrasts between areas of mountain beech and snow tussock, and between grazed and ungrazed tussock areas. The experimental work of the Forest Service in the Craigieburn area was also impressive.

The beech forest areas probably present a greater bulk of foliage, branches and roots than does tussock grassland, while dense tussock grassland must expose more plant surfaces both above ground and below it than tussock grassland in which the tussocks are widely separated by bare ground or minor herbs. It is well known that soil stability is related both to the type and amount of plant cover and there is no reason to doubt that the same basic relationships apply in New Zealand as well. What is not known is how much of each kind of cover—beech forest, dense tussock, modified tussock, minor herbs, etc.—is necessary to promote high infiltration and minimise soil loss from the high intensity rainfalls likely to be experienced in particular areas. The run-off plots established by the Forests Service are a much-needed start in this direction, but many more are needed both at Craigieburn and in other areas to obtain statistically reliable information.

Another striking difference between cover types, particularly beech forest and tussock grassland, is foliage colour. The forest canopy stands out dark green against the yellowish-brown areas of tussock. It seems likely, therefore, that more incoming energy is absorbed by the beech forest and that it uses more soil water as a result (up to 10-15 per cent is a reasonable estimate). A 10-15 per cent increase in water use in a catchment would make a worthwhile contribution to flood control, particularly as the other effects of beech forest—e.g., in promoting infiltration—probably operate in the same direction.

The Starvation Gully Exclosure of the North Canterbury Catchment Board demonstrates that depleted tussock grassland can respond to spelling from grazing provided the environment is not too severe and the period is long enough (e.g., 10 to 20 years). In this instance not only the snow tussock has responded, but also the spaniard (*Aciphylla*) and probably other herbs. The floristic contrasts which are now to be seen illustrate one of the important consequences of extensive grazing of more or less natural pastures—that livestock can be extremely selective in what they eat, as well as in the types of areas they most frequent. Hence large scale grazing even at low stocking rates (e.g., one sheep to five to ten acres) often means effectively very high rates (five to ten sheep per acre) in terms of the areas which are actually grazed. One of the main problems of extensive grazing is to obtain uniform utilisation, but where plants differ widely in palatability this is almost impossible to achieve. These remarks apply both to feral and domestic animals.

In addition to the hydrological experiments of the Forest Service at Craigieburn, species and transplant trials are being conducted, in which the performances of native and introduced species are being compared. Although not yet far advanced these trials are showing that several exotic trees (e.g., *Pinus contorta* and *Nothofagus antarctica*) may perform better than the native mountain beech even from the same area. This is in accordance with the poor performance of mountain beech under field conditions, particularly in the drier eastern areas of the Southern Alps where its tenure is unusually precarious. By contrast, forest growth on similar steep mountain slopes in Australia is difficult to eradicate, both because most of the trees themselves are resistant to disturbance including fire and because they have a strong capacity for regeneration. Such comparisons suggest that at least in the drier mountain areas the New Zealand flora is ecologically poor, particularly in tree species able to grow at the higher levels. Vast areas of tussock grassland below bush-line are potentially forest sites and it is also possible that trees could extend upwards a further 1,000 feet if suitable species were available.

Upper Waimakariri Catchment

A visit to Mr D. McLeod's property at "Grasmere" served to re-emphasise the critical importance of winter country in the management of high country grazing runs. In this instance, considerable success had been achieved by oversowing and topdressing a low sunny slope burnt several years ago. On the other hand, attempts to crop (with turnips) parts of the valley had been disappointing, possibly because of soil fertility factors. However, there is little doubt that provided moisture and temperature conditions are favourable for part of the year, profitable crops can ultimately be grown.

The burnt areas which had been oversown and topdressed had obviously improved as far as the establishment and growth of white clover and increased stock carrying capacity in winter were concerned. To maintain the clover, periodic top-dressing will be necessary at intervals determined both by pasture requirements and economic conditions. Two interesting problems present themselves, one relating to the nutrition of white clover and the other to its ecology and hydrological performance in tussock grassland.

Replacement of tussock grasses by white clover involves a change from deep rooting species with low nutritional needs to a shallow rooting species with relatively high nutritional demands. Since high country grazing will never be an intensive enterprise, it might be argued that, except in locally favourable situations, these measures are therefore contrary to ecological requirements for efficient use of the soil environment: species with low nutritional needs and a deep rooting system able to draw on the whole depth of soil for nutrients and moisture should be an objective, and ideally no follow-up topdressings should have to be applied. Apart from trees and native tussock grasses, cocksfoot seems to be the main pasture species which begins to measure up to these requirements.

The ecology of white clover establishment in difficult environments is understood to the extent that aerially oversown seeds are known to develop mainly in the shelter of existing species, rather than on bare ground. It is not yet known, however, how the development of the clover plants affects the original species. Does the clover spread mainly over bare areas, or does it spread at the expense of existing plants? Under favourable conditions it can spread over unoccupied ground, but in the more difficult tussock grassland environments this may not be the case. Thus the transect data of Mr R. D. Dick for tussock grassland areas in North Canterbury catchment show an increase in the percentage of clover in the community over the years, but no substantial decrease in bare ground. These results indicate that the clover has been spreading at the expense of other species in the community. From the grazing viewpoint this is of course advantageous provided it remains economic to topdress periodically, but from the hydrological viewpoint the changes are not necessarily advantageous. There is an urgent need for investigations into the relative merits of clover and tussock species for the control of surface run-off and soil loss. The best type of pasture is not necessarily the best type of catchment cover.

Molesworth (Clarence River Catchment)

The steps in the rehabilitation of Molesworth are well known. The progress which has been achieved to date has been due to the philosophy that livestock should be used as an economic means of rehabilitating depleted tussock country rather than as an economic end in themselves. The ability of the manager, Mr M. M. Chisholm, and the large size of the run (c. 459,000 acres) in relation to stock numbers (c. 8,000 head of cattle), have enabled this philosophy to be worked out on a practical basis. Systematic spelling of blocks, the use of cattle instead of sheep, pest control, and aerial oversowing especially with cocksfoot have been important measures.

The restoration of cover on many formerly largely bare slopes has been impressive. However, there are still many bare areas even at relatively low levels, and above about 4,000 feet improvement has been slight if in fact it has occurred at all. As in other high-country runs where rabbits have been brought under control, weeds such as sweet brier are increasing and on rough country where grazing returns are low effective control is not yet in sight. In fact, bearing in mind that tussock country up to about 3,000 feet is essentially a forest environment, woody weeds will almost inevitably increase unless useful plants with a stronger competitive ability can be found.

Waitaki Catchment

The Mackenzie Basin illustrated some of the climatic limitations to pasture development in the intermountain valleys of the South Island: low precipitations (13 to 20 inches per annum), strong drying winds, low temperatures in winter and high temperatures in summer with a wide diurnal range, and a high frequency of frosts which may occur at any time of the year. The generally infertile soils accentuate these difficulties.

Much of the tussock country inspected showed scattered tussocks, often pedestalled, separated by bare ground and various minor herbs especially sorrel. Despite low overall stocking rates it was again clear that the effective stocking rates in terms of the plants actually grazed (mostly minor herbs) must be very high. More efficient utilisation of these environments, which topographically are quite suitable for grazing, largely depends on being able to utilise all of the area, not just a small fraction of it.

The results both of plot and field-scale trials were seen on Dr K. F. O'Connor's plots near Mackenzie Pass and Lake Pukaki, and on the runs of Messrs R. Hosken and I. Wardell at Simon's Hill and Lake Pukaki. The plot trials seem to be showing that white clover can be successfully established in snow tussock areas in valley and fan situations but not on the higher slopes. From the viewpoint of the grazing animal a white clover-perennial ryegrass pasture was considered to be the goal. However this again raises the problems that the maintenance of such a cover requires periodic topdressing which in marginal environments might not be economic, that its shallow rooting habit is making inefficient use of the soil environment, and that it may not be the most suitable type of cover for maximum infiltration and protection of the surface soil against erosion. The experience of Mr Hosken so far was in favour of cocksfoot because of its ability to establish and maintain itself at low fertility levels. Mr Wardell was obtaining promising results from lucerne—another deep-rooting species but with higher fertility requirements.

Tara Hills

The Tara Hills Experiment Station near Omarama provided further opportunities for meeting workers engaged in various fields of tussock grassland research. It was obvious that considerable progress had been made in assesing for clover the nutritional requirements (e.g., for P and S) of many tussock grassland soils, in addition to the more general progress in pasture improvement of lower tussock grassland areas by oversowing and topdressing and effective programmes of rabbit control. The problem of reducing livestock concentration on sunny faces and redistributing them on less attractive (for the sheep) shady slopes was fully appreciated but unsolved. On the other hand, the hydrological effects of the alternative types of plant cover which were either being established or were proposed, in terms of surface run-off, soil loss and water use, were not yet known.

Lindis Pass

At Lindis Pass some contrasts between recently burnt and unburnt tussock grassland were demonstrated by Mr H. E. Connor. On the basis of preliminary work, 100 years or more was thought to be a reasonable estimate of the age of mature snow tussock plants. This estimate argues strongly against burning of snow tussock at higher elevations, unless some alternative stable cover can be substituted which in addition to proving more palatable grazing is an equally effective catchment cover. Above about 3000 plus or minus 500 feet no species appear to be available in the native or naturalised flora, which can be satisfactorily substituted for snow tussock.

The headwater creeks of the Ahuriri River, just north of Lindis Pass also provide contrasts with mountain creeks in most similar situations. The creeks near Lindis flow through dense grassland of red tussock and are largely stable along both their beds and their banks. Most creeks elsewhere now flow through a short, much-modified grassland, and are eroding vertically or laterally. Such conditions, which are now accepted by many people as being more or less natural, indicate the degree and rapidity of changes which have occurred in New Zealand vegetation probably within the last century. They also emphasise the need for a scheme of reservation by which representative examples of New Zealand environments, including the vegetation, will always be available in the more or less natural condition to serve as standards against which the effects of land use can be assessed, and as goals in certain types of reclamation projects. New Zealand's excellent system of national parks does not necessarily ensure that an adequate representation of vegetation standards is preserved.

Mid-Dome

The Mid-Dome Conservation Project, a Molesworth in miniature, provides another convincing example that a large measure of rehabilitation of lower tussock country is possible by the application of known measures. The essential philosophy is that livestock management is part of the reclamation programme, not an end in itself.

The success of lodgepole pine at the higher levels is in some respects the most interesting outcome of the project. It illustrates that the snow tussock environment up to about 4,000 feet is an ecological vacuum as far as woody plants are concerned, and a potentially suitable site for forest growth.

At the highest levels, however, little or no worthwhile recovery has occurred; there has been some seeding of native species but as yet no effective colonisation of bare ground.

Alexandra Area

The Central Otago District provided interesting variations on the preceding inspections, related mainly to the generally lower rainfall, the predominance of schistose parent materials instead of greywacke, and the block-faulted rather than steep-dissected terrain.

However, the main impressions of this area resulted from close contact with personnel of the Otago Catchment Board, and an appreciation of their organisation, problems, achievements and plans. It was surprising to find a profession such as soil conservation, some aspects of which are basically unpopular and which is generally regarded as a government function, supported so actively by the local community. Public support of Catchment Boards as essential links in the community chain between town and country is in some respects the most important achievement in soil conservation in New Zealand. The general acceptance of land use capability planning as the basis for sound land use was also impressive. Farm and catchment plans are no longer looked upon as expensive curiosities but as essential land use measures. The objective of a farm plan for every rural holding and a catchment plan for every catchment area, whilst still a long way off, is increasingly accepted as a possible goal.

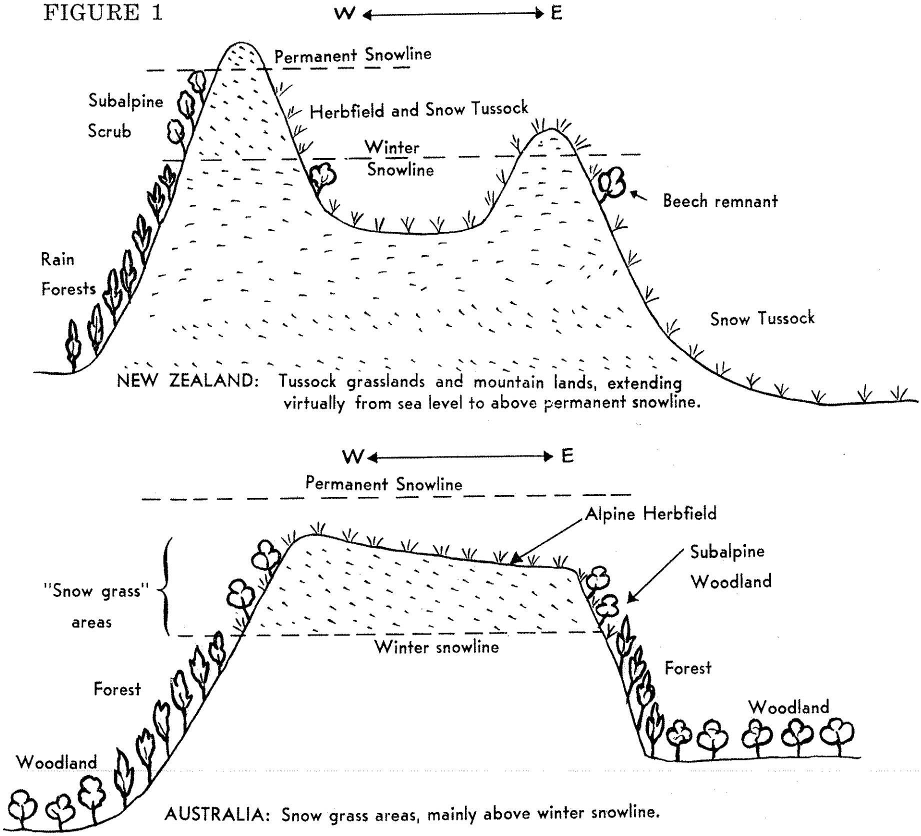
APPENDIX 2—SOME COMPARISONS WITH AUSTRALIA

A brief comparison of high country areas in New Zealand and Australia is helpful in defining, understanding and perhaps solving some of the problems.

The first obvious differences are in terms of types of environments and areal extent. The New Zealand tussock grasslands and mountain lands include a wider variety of major environments extending virtually from sea level to the permanent snow-line and above. The total area is probably more than 20 million acres, about 30 per cent of New Zealand. The snowgrass areas of the Australian mainland are virtually restricted to areas above the winter snow-line (4.500 to 5,000 feet). They occupy less than two million acres equivalent to about 0.1 per cent of Australia as a whole. Figure 1 indicates the general character of the respective environments.

Geologically, the mountain areas, at least in the South Island, consist predominantly of greywackes and mica schists, neither of which occurs extensively in the Australian Alps. These parent

FIGURE 1



materials and the extensive deep shattering to which they have been subjected combined with the steep slopes to produce generally well-drained terrain with a relative absence of swamp vegetation. In Australia, the parent materials are typically granites, slates and basalts which with the gentler slopes produce extensive groundwater areas, sometimes up to 10 per cent of a particular mountain plateau.

Climatically, both areas share a severe frost climate, with up to 200 and more freeze-thaw cycles during the year including many in the snow-free months. However, even allowing for differences in latitude, severe frosts are experienced at comparatively lower levels in New Zealand, due partly to the temperature inversion effcts in the large, enclosed intermountain valleys. Since these lower valleys and basins are not effectively insulated by winter snow which is meagre or absent, the number of freeze-thaw cycles at ground level may be considerably larger than in snow-covered areas higher up. The Australian snowgrass areas are all elevated and stand across the path of the prevailing SW-NW low pressure systems of Antarctic origin; thus they experience a rather similar climate with relatively heavy winter snow. In the Australian Alps about 35 to 150 inches is the annual precipitation range; in New Zealand it is less than 15 inches to more than 200. Strong winds are common to both environments.

Despite the wider range of climate in the New Zealand mountains, the vegetation pattern is more uniform than in Australia, with tussock grassland the predominant cover. This situation reflects the general ecological poverty of the New Zealand flora at least as far as cold and relatively dry mountain habitats are concerned. Thus the main tree species available, e.g., mountain beech and totara, are essentially rain forest species; there are no native trees which are able to grow in more open forest or woodland communities as natural transitions to grassland. It follows that the rate of spread of the forest even under favourable conditions is likely to be slow, and that damage to forest margins may result in their more or less permanent occupation by adjacent herbaceous vegetation, particularly under conditions tending to be unfavourable to the trees. The practical result is that the unusual predominance of tussock grassland dominated by closely related snow grasses has encouraged a system of grazing management geared more to the superficial uniformity of the vegetation than to the diversity of other environmental conditions (e.g., of elevation, aspect, temperature and precipitation), the significance of which the vegetation effectively conceals. Any system of management which remains essentially the same over a climatic range of several thousand feet is bound to break down at some places.

Another difficulty is that the widespread dominant grasses, the snow tussock group (*Danthonia flavescens, D. rigida,* and others), do not provide palatable grazing, although they are very suitable for catchment protection purposes. In the Australian Alps the snow grasses (*Poa caespitosa** group) present a similar problem. Thus the application of standard range management procedures of North America, in which maintenance of palatable dominants preserves both grazing and catchment values, is not directly applicable in New Zealand and Australia. This situation illustrates the point that grazing and catchment values are not necessarily related.

The success of weeds and animal pests in New Zealand also reflects the general ecological poverty and low competitive ability of the native flora and fauna. By contrast, the Australian high mountain areas contain virtually no serious weeds or pests, other than an occasional native species. Sweet brier is found only sporadically along roadsides up to 6,000 feet. Rabbits are a problem below 5,000 feet but are unable to thrive much higher, because of the length of the winter period under snow. Deer were introduced many years ago but have never become serious.

Although the New Zealand tussock grassland and mountain areas are much steeper and more extensive than in Australia, they are broken up by large relatively low valley systems which are suitable for permanent occupation. On the West Coast and on some of the wetter mountains east of the Divide these lower valleys are effectively fenced off from the higher areas by dense forest or scrub; however, there is virtually no such barrier on the eastern side generally and, except for relatively small pockets of forest, tussock grassland extends from top to bottom. The Australian high mountain areas

* Not the *Poa caespitosa* of New Zealand.

are mostly in the form of uplifted plateaux with relatively few large intervening valley systems and are further isolated by extensive mountain forests of eucalypts in which there is only very sparse grazing. Despite their smaller area and easier terrain, therefore, the Australian areas are more effectively isolated by natural barriers than those in New Zealand. In the past, a few mountain homesteads were occupied throughout the year, but as amenities improved in the lower, permanently settled areas these homesteads have been abandoned.

Economically, the Australian and New Zealand mountain areas are extremely important in Australia because they are so few and in New Zealand because they are so extensive. About half of the irrigation water for south-eastern Australia flowers from about 2,500 square miles of high country and this water also produces a large amount of hydro-electric power. On the other hand, actual and potential production from grazing are very slight even assuming fullest development as a grazing proposition. Up till 1958 the snow country in New South Wales and Victoria was held for summer grazing under one to seven year leases, in conjunction with lower freehold land which in almost all cases constituted living areas. In 1958 most of the high country in New South Wales was withdrawn from grazing. This action followed appreciation of its unique importance as a source of water for irrigation and hydro-electric power compared with its almost negligible value for grazing. Because of this uniqueness it also has high national park value, the maintenance of which in the strict sense is incompatible with grazing by introduced animals.

In New Zealand, where the tussock grasslands and mountain lands cover a much larger area, they are of considerable importance to the grazing economy, particularly for the production of fine wool. They also produce an abundance of water. It is unlikely that there will ever be insufficient water for irrigation, except perhaps locally. Hydro-electric development has so far been relatively slight, although the potential is enormous. At the moment, therefore, water is regarded more as an embarrassment than an asset, because of periodic heavy flooding especially of fast-flowing streams, and the consequent damage to primary production, roads and bridges, and threat to towns. For a considerable time to come, land use in New Zealand tussock grasslands and mountain areas will probably be viewed mainly in the light of flood-protection and grazing.

Administratively, both areas are confused, with many government and semi-government agencies involved, sometimes with divergent policies and with no single effective authority overall. It seems to be a paradox of the conservation movement throughout the world that the increasing awareness of conservation needs is being met by increasing fragmentation of responsibilities and competition between the various users and managers of land resources. In both countries there have been attempts to clarify the position—for example, through the Catchment Areas Protection Board of New South Wales, the Land Use Advisory Council of Victoria, and the Tussock Grasslands and Mountain Lands Institute of New Zealand, but a large measure of divided and independent responsibility remains. Such groups should themselves be in the forefront of land-use research, otherwise they will have difficulty in deciding what are the key problems, and in assessing the relevance and value of research results.

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