THE IMPLICATIONS OF PAST EXPLOITATION AND CURRENT DEVELOPMENTS TO THE CONSERVATION OF SOUTH ISLAND TUSSOCK GRASSLANDS

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SUMMARY: In a cultural-ecological perspective of New Zealand pastoralism the amount and form of energy supplements at different stages of pastoral development are characterized and prospects for sustainability discussed.

The history of the pastoral exploitation of the tussock grasslands of South Island, New Zealand is reviewed with particular attention to physiognomic changes brought about by early fire and grazing.

Current changes in farming on high country mark an end to the exploitative phase of use of the tussock grasslands and promise a transformation of some existing grassland communities into entirely different associations.

The opportunities and needs for biological reservation of tussock grasslands are re-examined in the light of the changes that have been already induced and of the development now occurring.

INTRODUCTION: NEW ZEALAND PASTORALISM IN A CULTURAL-ECOLOGICAL PERSPECTIVE

The pastoral use of New Zealand terrain which has been so characteristic a feature of recent history, both economically and geographically, has been of different kinds. At one end of a cultural-ecological continuum, graded by auxiliary energy inputs, is what may be termed factory-farming, including some forms of horticulture, pig and poultry raising. Intermediate are field cropping and highly intensive pastoral farming. At the other end of this spectrum is what has been recognized as extensive pastoralism. I have recently termed the traditional form of this extreme as "exploitative pastoralism" (O'Connor, 1981) because it sought to make use of existing plant resources with virtually no application of energy directly to their augmentation, maintenance or replacement. In this once widespread cultural form, energy was principally used in human management, devoted almost entirely to the manipulation of live. stock, as stockmanship. As pastoral farming is intensified, both volume and forms of energy input change. An indication of these changes is presented for the typical pastoral farming classes of South Island, New Zealand (Fig. 1).

From time to time, highly intensive pastoral farming has excited the apprehension of some New Zealand ecologists lest it be not sustainable. Such fears have been voiced because intensive pastoral (arming appears to be structured on associations of few plant species of comparatively narrow genetic base and with even fewer animal species, and because it depends heavily on energy supplementation, especially as fertiliser. Some comments may stimulate further more critical debate of the issue of sustain ability.

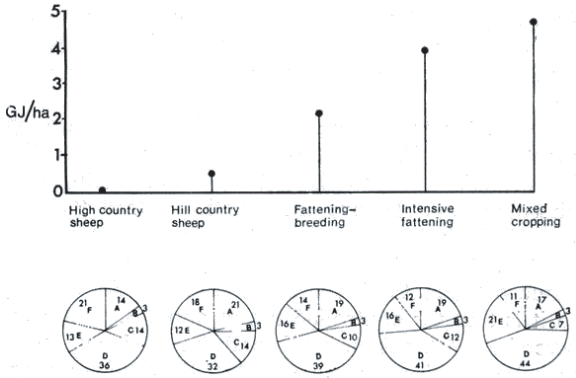

FIGURE 1. *Typical energy intensities (GJ /ha) for pastoral farming systems in South Island, New Zealand, together with percentage contribution of auxiliary energy in (A) fertilizers, lime and seed, (B) animal health, control of weeds and pests, (C) contract work and cartage, (D) fuel and power, (E) machinery,* (F) *other (including buildings, fencing, water supply). Source: Smith & McChesney (1979) from Economic Service of Meat & Wool Boards data from farm surveys in mid-I 970s.*

First, highly intensive pastoral farming in New Zealand is now far from being a monoculture, either in a landscape, as the term monoculture perhaps should be properly applied, or with respect to the biota involved. Further, its monocultural trends are currently being reversed, with increasing numbers of species being selected and bred for different physical and management niches, and with some increase in the complexity of pattern with which pastoral components are integrated into land use systems. In this respect, one cannot but be interested in the parallels between intensive pastoral farming and the vegetation-herbivore relationships revealed by McNaughton (1978, 1979, 1979a) from the Serengeti, one of the most sustained and productive vegetation-ungulate systems on earth.

Second, there is substantial evidence, in research and practice, that the energy supplements of intensive pastoral fanning do not need to be as large as they have been in recent years. In particular, application of energy in fencing and grazing management can achieve considerable economy in cultivation and clearing, fertilizer use, weed control, fodder production and conservation, all of which are calculated to have high energy inputs (Brown and Pearson, 1977; Dawson, 1978; McChesney, 1979).

Third, the traditional pattern of pastoral development in New Zealand has its ecological justification in Walker's (1964) thesis that topdressing with superphosphate and legume introduction retard the ecological clock of succession. It is an implied premise of that thesis that productive yield is higher in induced "immature" successional stages. A corollary to it is that the controlled use of animals, to prevent reversion to bracken, scrub and forest (Levy, 1970), recycles nutrients and provides light regimes for further legume growth and nitrogen fixation (Sears, 1956), and contributes to the maintenance of ecosystem immaturity and the further increase of yield.

There can be little doubt of the ecological and economic validity of this thesis in hill country development over a wide range of New Zealand conditions. What may be questioned on both ecological and economic grounds, however, is the competence or adequacy of the thesis in two distinct but related situations. One occurs when natural soil fertility is extremely low and the needed amounts of fertilizer and other high-energy inputs such as land clearing and drainage are so high as to be unmatched by the yield benefits. The other occurs where the marginal costs of further increasing yield or the costs of maintaining yield at very high levels are so high as not to be justified in financial or energy accounting.

Both situations tend to be distorted by subsidies, development incentives and like interventions. The pastoral ecologist, economist and land user share the task of discerning at what cultural level on different soils, productive yield can be frugally and economically maintained. This may lead to some soils not being developed for pastoral farming. Other more fertile, or more easily maintained, soils would have preference. In the present incentive-laden climate, one might expect pastoral development to make substantial inroads into the reservoir of undeveloped resources, especially when incentives are tailored specifically for application to undeveloped, even marginal land. When fertilizers are heavily subsidized, one might expect the second kind of earlier-described situation to occur, with yields being maintained above true economic levels.

The sustainability of extensive pastoralism has been subject to doubts of a different kind from those directed at intensive pastoralism. As the Tussock Grassland Research Committee (1954) observed, extensive pastoralism in the South Island high country has been the occasion of scientific disquiet from its inception. The historical record of scientific concern for the sustainability of extensive pastoralism, especially dealing with fire and soil erosion has been reviewed elsewhere (O'Connor and Powell, 1963; O'Connor, 1980). The particular focus of the present paper is the effects of the early decades of exploitative pastoralism on the condition of vegetation and thereby on the likely outcome of present or future reservations for nature conservation. The prospective interactions between pastoral development and nature conservation for science are examined in conclusion.

THE ECOLOGICAL STUDY OF EXPLOITATIVE PASTORALISM

Exploitative pastoralism in New Zealand has been almost universally identified with the tussock grasslands of South Island. In former times, it was also associated with open country of the upper Rangitikei, Hawkes Bay and Wairarapa in North Island and was practised on the mountain grasslands of Westland from about the turn of the century to as late as 1930s. It persists on some of the lowlands of Westland and other districts, not merely in the use of the seral vegetation of alluvial ground, but in the use of forest stands for the wintering of livestock, and in the continual access to unprotected forest remnants by livestock at any time of the year. For conserving biota and as reference areas for biological processes, it is valuable to identify such threatened forest remnants and amend their exploita-

TABLE 1. *Pastoral growth and land utilization in Nelson, Marlborough, Canterbury and Otago (including Southland) from 1861 to 1901. (Source: Evans. 1956).*

	1861	1871	1881	1891	1901
Livestock Numbers ($x10^3$)					
Sheep	2,121	7,826	8,863	10,349	9,988
Cattle	97	252	303	275	321
Horses	15	46	100	111	117
"Sheep-equivalent stock-units"	2,694	9,361	10,477	12,393	12,293
Land utilization (ha x 10^3)					
A. *For livestock*					
Sown pastures	13	135	593	1,271	1,716
Brassicas etc.	1 (e)	6 (e)	87	132	132
Oats (chaff etc.)	1 (e)	4	16	45	55
Sub-total	16	145	696	1,448	1,903
B. *For harvesting*					
Cereals and pulses	11	85	223	256	261
Potatoes	1	2	6	9	6
Total under cultivation	30 (e)	263	1,021	1,773	2,237
Land sown for livestock feeding (ha per 1000 stock units)	6.1	1.5	66.4	116.8	154.8

(e) estimated from national figures.

tion, especially in areas of pastoral development (Overmars, 1981). While a special case can be made for preserving wetlands, the major zones requiring protection from continued exploitative pastoralism continue to be the tussock grasslands.

The exploitation of South Island tussock grasslands has been commented on by many different writers, often with considerable emotion, ranging from nostalgic affection to indignation. A careful historical and geographical analysis of the exploitative culture has yet to be done in an ecological framework and on an island-wide scale, although some general accounts have been written (Thomson, 1922; Clark, 1949) and some sub-regional analyses have been attempted (O'Connor, 1976, 1980). As a consequence of this neglect, ecological assessments of human influence have hitherto been concentrated on studies and reviews of particular factors involved in exploitation, such as fire in the tall tussock grasslands of Otago (Mark, 1965a) and Canterbury (O'Connor and Powell, 1963), or to the botanical appraisal of the cumulative effects of pastoral exploitation. This latter approach is seen in the classic work of Petrie (1883, 1912), Cockayne (1919-22, 1928) and, more quantitatively, in the phyto-sociologic analyses of Barker (1953), Connor (1961, 1964, 1965), and in the largely unpublished watershed surveys of the Protection Forestry Division of the New Zealand Forest Service, e.g. Wraight (1963, 1967).

The paucity of historical cultural analysis may lead to confusion of objectives in resource management and conservation, not least in biological conservation itself. In particular, some important features of the early history of pastoral exploitation in Marlborough, Nelson, Canterbury and Otago (including Southland) may have been underestimated in their effects on the composition and distribution of the tussock grasslands themselves.

CHANGES IN LIVESTOCK NUMBERS IN PASTORAL HISTORY

O'Connor and Kerr (1978) have demonstrated the rapidity of pastoral occupation of open country in South Island, New Zealand. Most of the plains and downlands were pastorally occupied by the early 1850s. Local and pastoral histories (Gardner, 1981; Acland, 1951; Pinney, 1971, 1981; Vance, 1965; Duff, 1978; Parcell, 1951; Roxburgh, 1957; Beattie, 1947a) reveal that most of the high country was taken up in runs by the late 1850s and the last of the gorge runs by the early 1860s.

Table 1 summarises the changes in livestock numbers and land use for the next four decades for the

combined areas of Nelson, Marlborough, Canterbury and Otago (including Southland). Nelson is included because, prior to 1916, the Nelson Provincial District included what became Amuri and Cheviot counties, important Nortil Canterbury tussock country areas. Nelson Province was important also as a colonisation centre for the early pastoral expansion southwards. "Sheep-equivalent stock-units" have been calculated by treating each sheep as 1, multiplying numbers of cattle by 5 and numbers of horses by 6. No account is taken of goats, rabbits, pigs or other animals.

It is evident from the table that all classes of livestock, supplemented by importations from Australia, increased at fantastic rates during the 1860s; from 1861 to 1871 the overall increase in stock units was 247 %. In three subsequent decades the rates of increase were 11.9%, 18.3 % and -0.8 %. Sheep numbers in these eastern provinces actually reached an initial peak of nearly 9.5 million by 1878. Total stock units reached over 10.6 millions as early as 1874, and over 11.3 millions in 1878, before declining to 10.5 millions in 1881 (Evans, 1956).

What should be emphasised is that the first great increase in livestock in the 1860s and early 1870s was made without provision for their feeding on other than the natural pasturage of the native grasslands and those induced by burning forest and flaxland (Travers, 1870). The ratio of land improved for livestock feeding per 1000 stock units reached its lowest value in 1871. With the increase in turnips and grass sown during the 1870s, this ratio progressively increased. However, the first peak of sheep population was almost entirely gained by chewing into the native pasturage.

The grain boom in Canterbury and Otago did not reach large proportions until late 1870s when 250,000 ha were in grain and pulse crops for threshing, including over 100,000 ha in wheat. Sowing of pastures expanded in advance of this bonanza period and continued during and after it, leading to a second peak in sheep numbers in 1886, following the introduction of refrigeration. From then on, sheep numbers declined and never recovered to the 1886 level in Otago for 23 years, nor in Canterbury for more than 40 years. This decline in sheep population and the subsequent long stagnation occurred despite the steadily expanding acreage of sown pastures.

It is impossible to avoid the conclusion that the sheep population on unimproved grasslands no sooner reached the end of its "eruptive phase" (Riney, 1964) than it began to decline. My analysis of the Vincent and Lake County statistics from 1880 to 1952 (O'Connor, 1980) demonstrated that the decline in calculated livestock load on unimproved range continued erratically for 70 years, to a level only 10% of that in 1880. My recent notes on trends in the Waitaki and Waimakariri catchments, revealed somewhat similar declines (O'Connor, 1981).

What is indicated from the present account is that a livestock population peak was attained by the early 1870s, was attained on native grasslands, and was not sustainable on them. This general thesis is in part supported in local studies, although the dates at which population peaks have been achieved may be somewhat later in the high country sector where runs were settled up to a decade later. For example, Duff (1978) suggests that at Morven Hills, Otago the peak was reached in the mid 1870s, within 20 years of first settlement, and Pinney (1971, 1981) has cited some records which indicate a similar time span for peak sheep population to be reached on individual runs in the Upper Waitaki and Mackenzie Country. Without careful analysis on this particular theme, it is difficult to reconstruct population histories or postulate the causes of their variation.

The Effects On Scrub Of Initial European Fire

In exploration, in the initial droving of livestock to a new run, and in the conditioning of a tall grassland for the grazing of sheep, fire was a widespread and important feature. From accounts of many of the pioneering runholders and explorers in coastal ranges and in inland Canterbury, it is inferred that scrub and speargrass *(Aciphylla)* were important elements of the vegetation. Even in recent times, Burrows (1969, 1969a) has recorded the wide distribution of many shrub species and indicated the complexity of many of the scrub communities. Such communities would have been recovering at various stages from the periodic fires of Polynesian occupation (Molloy, 1969). Early European fires, "opening up" the country, would have been initially destructive of shrubland physiognomy, provided that the woody species were not fire resistant. Mark (1955) at Maungatua, Otago and Connor (1965) in the middle Rakaia emphasised the role of fire in shrub suppression, especially of the epacrid *Dracophyllum*.

A similar pre-fire, scrubby physiognomy is indicated from the inland Otago grasslands both in the subalpine and lowland to montane zones. This is evident from the accounts of the journeys of Thomson, McKerrow, Buchanan, Hector and others in the late 1850s and early 1860s (Beattie, 1947). Buchanan (1875) pointed out the futility of burning in arid areas because of the recovery from fire of speargrass.

Scrubbiness is confirmed by the persistence of small shrubs on the occasional torsbearing soil, and in other situations where they have been preserved from fire and grazing. It is also indicated by the persistence and recovery in the semi-arid zone and the subhumid zone of the Waitaki of extensive shrublands, not merely of *Discaria* but of *Olearia, Coprosma, Podocarpus, Sophora, Pimelea, Muehlenbeckia, Carmichaelia* and other genera, including in some localities *Dacrydium* and *Phyllocladus*. In the Upper Clutha not only are semi-arid and subhumid slopes marked by *Leptospermum* shrub land (Burrell, 1965) and *Podocarpus hallii* groves (Wells, 1972), but occasional remnant trees of *Sophora microphylla* are still standing in depleted grassland or induced desert.

In view of the historic evidence for fire at the outset of pastoral occupation, it is highly probable that the first impact of fire in European times was to convert a mosaic of shrub thickets and scrubby grasslands, at least temporarily, into a physiognomic grassland, such as that which so pleased the eye of Lady Barker in 1867 (Barker, 1883). If this indeed be true, there is little need for wonder that the reduction of burning in later years, together with sustained grazing pressure on palatable herbs, resulted in the recovery of vegetation that is often as much scrub as grassland (cf. Primack, 1978). Reduction in grazing pressure, along with the recent cessation of burning in many localities, has allowed the physiognomic emergence of plants such as *Aciphylla* and *Carmichaelia* which were previously suppressed by grazing.

The Reduction In Stature And Depletion Of Grasses From Early Pastoralism

The second dramatic effect of early pastoral exploitation was the reduction in stature and density of the grasslands. The evidence produced here of a very rapid growth in livestock populations, and the evidence from many historical sources of regular and repeated burning (Butler, 1863; Barker, 1883; Buchanan, 1875; Beattie, 1947a) indicate that, over many areas, the stature of grasslands would have been considerably reduced in very short term. Writing in December 1867, Lady Barker (loc. cit.) laments: "I sigh over these degenerate days when the grass is kept short, and a third part of a run is burned regularly every spring, and long for the good old times of a dozen years ago, when the tussocks were six feet high. What a blaze they must have made!" Lady Barker's report on tussock stature is hearsay, for she reached New Zealand in 1865. Her reference to regular burning is from her own experience.

There are few early detailed descriptions of .the physiognomy of grasslands that allowed later comparison. One of the few published (Buchanan, 1875) is recognized, from Lady Barker's account "Buying a Run" (Barker, 1873), as in a locality less likely to have had intensive burning and rapid stocking up to capacity. What Buchanan (1875) described from the 1860s as a forest or "coarse unnutritious grasses" midslope on Mt Alta in the Lakes district of Otago is now clearly *Chionochloa rigida*. It may have been already recovering from burning, for the block was already stocked with sheep. It was evidently a taller and denser grassland than it is now. He found sheep grazing at higher altitudes on the finer grasses amid what is now recognised as the shorter C. *macra*. Now the snow tussocks remain, albeit shorter and perhaps less dense, but with much less conspicuous inter-tussock fine grasses. Apparently inter-tussock vegetation has been depleted at high altitudes and modified at midslope by the ingress of adventives. How rapidly such changes occurred must remain a matter for speculation or historical simulation.

The immediate effect of burning, accompanied by initially very high grazing pressures, on recovering *Chionochloa* grasslands can be interpreted from experiments. Williams and Meurk (1977) showed that C. *rigida,* recovering after fire, had higher concentrations of nitrogen and minerals than unburnt tussock. Such herbage is more readily eaten by sheep. The effects of fire and of repeated defoliation on *Chionochloa* tussocks have been assessed experimentally by O'Connor and Powell (1963), O'Connor (1963), Mark (1965a), Payton and Brasch (1978), and Payton and Mark (1979). A model for the response of tall tussocks under different stocking conditions is illustrated in Figure 2. While actual values will vary with tussock species, climate, alternate forage supply, as well as rate of sheep increase, the illustration shows the special significance of increasing livestock numbers in accelerating the demise of tall tussocks.

The eventual physiognomies and compositions of the grasslands of Canterbury (Cockayne, 1928; Zotov, 1938; Barker, 1953; Connor, 1964, 1965; Connor and Macrae, 1969) and Otago (Petrie, 1912; Cockayne, 1928; Zotov, 1938; Mark, 1955, 1965; Connor, 1961; Mark and Bliss, 1970; Meurk, 1978) can be interpreted as the outcome of fire and grazing by depletion, reduction in stature, increase of fire-tolerant and / or unpalatable plants, and invasion by exotics, including especially annuals. Early, low-altitude depletion of tall tussock and its conversion

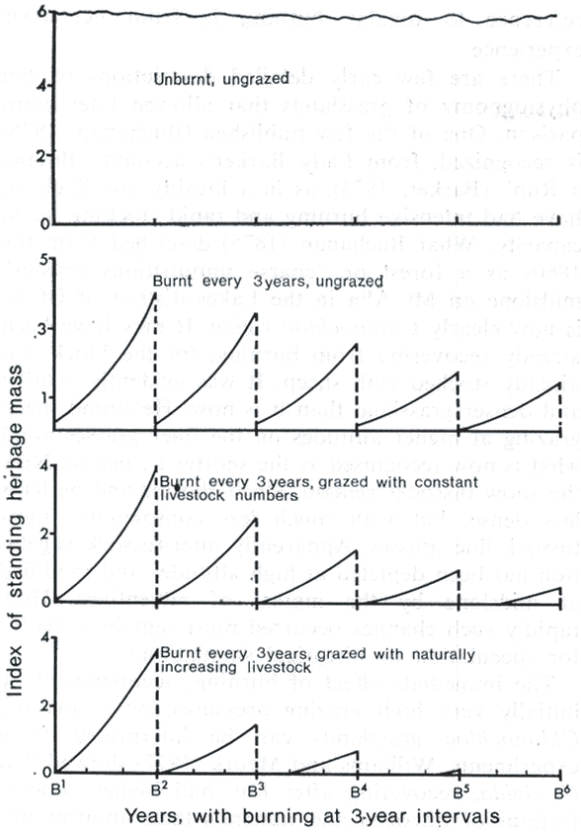

FIGURE 2. *Schematic representation of changes in standing herbage mass of* Chionochloa *tussocks as affected by burning at three-yearly intervals under different livestock-grazing regimes.*

to short tussock grasslands are indicated from Connor's (1964) account of the Mackenzie grasslands. Many of the shorter grasslands of higher-rainfall Canterbury districts, and of Marlborough, were induced by early burning of forest, scrub and flax land (Connor and Macrae, 1969; Molloy, 1969; Monro, 1868). Early modification of drier grasslands of Otago is indicated from contemporary descriptions (Buchanan, 1875; Petrie, 1883). Progressive depletion in that sector is recorded from Petrie (1912), Cockayne (1928), and Zotov (1938). Early, high-altitude depletion of C. *macra* in Central Otago communities, which has been argued by O'Connor (1976a, 1980), would be consistent with the early rapid growth in livestock numbers demonstrated here.

Whitehouse (1978) has assembled early photographic records of mountain condition in Canterbury. These records are valuable for their demonstration that soil and vegetation conditions have not greatly deteriorated since the early photographs were taken from 1880s to 1905. However, considerable caution should accompany any inference that changes were not induced or accelerated by European pastoral occupation, unless photographs or other records were made well before 1880. (cf. Travers, 1870). There is little doubt that responsibility for land deterioration as soil erosion in certain zones of Canterbury has been excessively attributed to pastoral occupation, by such writers as Gibbs *et al.* (1945), Cumberland (1944), and Raeside (1956, 1960). There is, however, considerable support for the suggestion of Zotov (1938) that exploitative pastoralism had set in train the depletion of grasslands before rabbits *(Oryctolagus cuniculus)* became a pest of major proportions. Indeed, it would seem that the dramatic speed with which rabbits became a critical problem may be best explained, not just by their fecundity, but by the declining herbage resource of the habitat into which they came.

THE FUTURE OF PASTORALISM IN TUSSOCK GRASSLANDS

Over the past 100 years, exploitative pastoralism has been in decline. Over the last 25 years, it has been gradually undergoing a metamorphosis in the high country (O'Connor and Kerr, 1978; O'Connor 1981), whereas it underwent a rapid transformation on the Canterbury Plains approximately a century ago. There are now at least four valid, potentially viable and sustainable land uses which can succeed exploitative pastoralism in the hilI and high country. One of them, pastoral farming of a progressively intensifying character, has already started. Another, resource-based recreation, is already established in some localities, often as an adjunct to pastoral farming (O'Connor, Smith, Tan and Gresham, 1982). Another use, production-protection forestry has been demonstrated to have very high potential on some terrain (Nordmeyer, 1979, 1980; Benecke and Havranek, 1980). The fourth, nature conservation for science, education, aesthetic or spiritual appreciation, or simply as a part of natural heritage, is at present confined to National Parks in high rainfall zones, some unoccupied Crown lands, a very few reserves, and some "protection" lands of State forests and Forest Parks.

None of these four uses is equally suited to all terrains in the high country. The compatibility of extensive pastoralism with each of them is generally low, apart from some sectors of resource-based recreation. The compatibility of intensive pastoral

TABLE 2. *Livestock loads in relation to land improvement on Waitaki pastoral runs and to all South Island pastoral runs.*

	Unimproved Grazing land	Topdressed Grazing land
Mean Area (ha) for S.I. Pastoral Runs (288)	9,688	1,256
Mean Area (ha) for Waitaki Runs (82)	8,775	868
Mean Area (ha) for Waitaki Sample (27)	7,706	744
Mean Annual Stocking Load (s.u.'s/ha) for Waitaki Sample (27)	0.32	3.0

farming with each of these uses is, likewise, generally low on the same precise site. The opportunity for complementarity among these uses on different sites within the same zone is very great, but is not without problems (O'Connor, Batchelor and Davison, 1982).

To understand the implications of likely changes in the near future, it is necessary to form some idea of the changing character of pastoral farming. The present, somewhat tentative phase of grassland improvement in the tussock high country has already resulted in a substantial reduction in the stocking load on unimproved grasslands, as shown (Table 2) from a survey of land use on all runs (Kerr, Lefever and Costello, 1979) and analyses of individual block stocking loads of Waitaki runs (O'Connor, Costello and Kerr, 1982). Were economic conditions to deteriorate, pastoralists with existing tenure might wish to exploit once more this resource of unimproved land. A similar risk might belong to land already retired from grazing use if it recovered as an outcome of sustained rest.

At the present time, however, a new phase of pastoral development is occurring. Closer subdivision with both fixed and movable fencing is leading to rapid improvement in pastures already topdressed and oversown, and to further increases in livestock numbers and performance. The inter-tussock swards of such grasslands are increasingly of exotic grasses and legumes. Few native species, once important in the ground stratum, now survive in abundance. Whether the tussock canopy itself is maintained is determined by terminal grazing pressure in a rotational grazing system. Farmers who wish to retain tussock for its value as lamb shelter, or as a conductor for melting and breaking snow, may do so by careful grazing management. The important feature for those concerned with nature conservation, is that persistence of a tussock grassland in such grazing regimes following topdressing and oversowing, is only the persistence of the physiognomic shell.

Even apart from this transforming treatment, many tussock grasslands, especially in the montane and lower subalpine zones, have already undergone a floristic transition in their inter-tussock ground stratum. If such modified tussock grasslands are protected from grazing, some of the exotic elements already present may dominate either visually, as by hawkweeds *(Hieracium* spp.), or by suppression of short tussocks, as by cocksfoot *(Dactylis glomerata)*. Exotic shrub or tree species may invade grasslands under low grazing pressure in many localities. Exercises in biologic conservation by exclusion of livestock and fire may be interesting biologically but sometimes futile in conserving the native flora and dependent fauna.

NATURE CONSERVATION AS A USE OF TUSSOCK GRASSLANDS

The purpose for which nature conservation may be practised as reservations of various kinds include science and education. The criteria by which such reserves should be selected include representativeness (Dingwall, 1976; O'Connor and Molloy, 1979; Mark,

1980). The unrepresentative character of our existing reserves has been pointed out by Knox (1979) and Scott (1979). Naturalness, in the sense of pristine condition, although desirable, may not be always as important for the purpose of science as it is for other purposes.

As pointed out by Scott (1979) and O'Connor and Molloy (1979), tussock grasslands have been neglected as nature reserves. This neglect has occurred despite their considerable use for scientific purposes. Scientists may have been lulled into complacency because of seemingly abundant supply, a condition from which they must be aroused, as much in the interests of economic development as in the interests of effective science.

Because of the depletive changes of past pastoralism, and the enriching changes of current pastoral development, nature conservation, for science or any other purpose, must now compete with other suited uses for limited, natural grassland resources. This

competition is especially acute for lowland, tall tussock grasslands and for short tussock grasslands in "natural, good condition", not just because of their increasing scarcity but because of their value for other purposes, especially pastoral development (Scott, 1979).

Earlier in this paper, it has been shown how the application of sound economic and ecological principles leads to the preferential development, for farming, of more fertile or more easily maintained soils. Nature conservation, as a valid social use of land cannot be content, however, merely with the residues from development whether these be in forest, grassland or wetland, for such residues would be unrepresentative of the spectrum of nature and would lack relevance to land under development. To justify reservation of natural vegetation on more fertile soils, the ecologist may often have to argue the relevance of its natural processes to the efficiency of processes affecting the sustainability of developed land use systems.

There is now 'an elaborate administrative and management framework for biosphere pro'ection" (Dingwall and Miers, 1979) as well as enabling legislation in the Land Act and the Reserves Act. Following the New Zealand Government (1979) statement of policy guidelines, nature conservation is now acknowledged as an integral part of its High Country Policy by the Land Settlement Board. Nevertheless, there is lacking a clear and effective intention for reservation of representative areas of New Zealand's tussock grasslands, especially where these grasslands have a potential for pastoral development. Perhaps what is most lacking is an understanding of how the scientific monitoring of grasslands in natural and degraded condition, in conjunction with grasslands under development, can contribute to the economy and success of the pastoral development process. This feature has been demonstrated already by the Forest Research Institute studies in the Craigieburn Range on comparative phytomass and nutrients of unimproved grasslands (Evans, 1980) and native and introduced forests (Nordmeyer, 1980, 1980a), as well as on comparative physiology and performance of tree species (Benecke and Havranek, 1980, I 980a). What has not been appreciated is that comparative studies of gas exchange, energy flow, and nutrient cycling are vital to assessments of sustainability of pastoral development, especially in marginal environments. As pointed out in a recent review of nitrogen balances in natural grassland (O'Connor, 1983), New Zealand has neglected to exploit its initial leadership in the field of geobiochemical nutrient flows. Failure to reserve grasslands of different kinds and conditions as benchmarks for such comparative studies, will eliminate future opportunities for research relevant to land uses on which New Zealand economically depends. Promotion of pastoral development, whether by changes in tenure or other means, demands as a counterpart, urgent commitment to adequate representative and effective reservation of tussock grasslands for the science essential for successful development.

The necessity for biological preservation and for comparative monitoring of natural and cultural systems as an integral part of a nature conservation strategy demands that New Zealand reserve many, substantial, "natural" areas in the tussock grasslands. It also requires the identification and preservation of examples of modified or degraded systems (e.g. Connor, 1964; Williams, 1980, pers. com.). Because reserved grassland may eventually succeed to a shrub land, reserves may need to be large enough to accommodate both fired and unfired areas. For many, controlled grazing may be essential. For at least some, the re-introduction of grass-dwelling birds such as the weka *(Gallirallus australis),* once an abundant and integral part of the system, may be desirable.

At higher altitudes, large areas of slopes, whole catchments, or even whole mountain tops, such as the Garvie Mountains in good condition and the Old Man Range in poor condition, need to be reserved. To protect the Garvie summit may require that recreational use be confined to winter wilderness experience in cross country ski-ing. For the Old Man Range, scenic enjoyment recreation may be compatible with the protection of a much modified and recovering system. Other ecological districts have similar needs for reservation but may have different requirements.

What is clear is that reservation for science needs to be an integral part of nature conservation. Nature conservation can often be integrated with other uses on the same terrain but must be planned along with development, in the integrated future of any district or region. A century ago, pastoral exploitation without adequate scientific appraisal had disastrous consequences both ecologically and economically. As a nation, New Zealand foolishly persisted with it (O'Connor, 1980). Almost a century elapsed before a partnership of science and practice extricated high country pastoralism from a downward spiral to ruin and redirected it to a viable path. Some further centuries will probably be needed before natural conditions could be reconstituted on land abandoned from pastoralism. It would be equally foolhardy for New Zealand to embark on a full

programme of high country pastoral, agricultural or forestry development without providing for a scientific partnership in both nature and culture to assure the sustainability of development.

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