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A review of fire management in rural New Zealand

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Outlines of current issues

Introduction

The often widespread incidence of wildfires in rural forests, scrublands and grasslands inevitably affects a range of people and agencies with an interest in land management. The fire hazards of the largely tussock grassland-covered high country of the eastern South Island have been the subject of particular inquiry (Department of Lands and Survey, 1969; New Zealand Forest Service, 1974). This paper is a review of the management of fire in rural areas, with particular reference to the hill and high country of the South Island.

Legislation

The present legislation 'relating to the safeguarding of life and property by the prevention, detection, control, restriction, suppression and extinction of fire in forest and rural areas and other areas of vegetation' is the Forest and Rural Fires Act 1977. This Act had its origin in 1885 following the 'disastrous' fires which destroyed areas of Kauri forest in the Puhipuhi Forest in Northland (Reed, 1964). Initially the legislation was directed at offenders who lit fires in forests. Eventually, after successive amendments to the Counties Act and the Forests Act, the first Forest and Rural Fires Act of 1947 was promulgated with the purpose of protecting areas other than State forest. The Act did this by creating three types of rural fire authorities - Minister of Forests, Rural Fire Districts, and local authorities - and enabling these authorities to 'declare closed fire seasons, requisition manpower, and appoint fire officers' (Cooper, 1980). An amendment to the 1947 Act (in 1955) provided for integration of State and other fire authorities within one statute and set the scene for the present legislation.

The present legislation provides for District, County and Borough Councils, the State (as the Minister of Forests or the Minister of Defence) and especially created Rural Fire Districts to be fire authorities. The Act, in its long title, requires all uncontrolled fires in rural areas extinguished by the relevant fire authority. It is the duty of every fire authority to promote and carry out fire control measures including a written fire plan in its district (S 12.1 of the Act).

The Act enables strong powers to be exercised by any fire authority which 'may at its discretion, promote and carry out such measures it thinks fit...' (S 12.2). Such provisions include the appointment of Principal Fire Officers (and deputies) with powers to enter upon land (with or without equipment), requisition equipment, take whatever measures 'which in the circumstances are reasonable' or 'necessary or expedient' (including the destruction of property), take control of water supplies, and control thoroughfares (S 36).

The Act makes provision for the relevant fire authority to recover the costs of fire control measures from the persons responsible for the outbreak, or a levy may be imposed on the beneficiaries of the control measures

(S's 43, 46). The recovery of these costs is by way of agreement between the fire authority and the person responsible (or a contracting insurance company), or by the decision of a Rural Fire Mediator (appointed for the purpose), or recovered as a debt in a Court.

For any county area comprising hill and high country land, the fire authority is required, (Reg. No. 4 of Forest and Rural Fires Regulations, 1979) to compile a fire plan; provide dates and details of fire seasons; issue special permits to burn; maintain an up to date record of firebreak tracks and of available equipment; make two-way radio facilities available when required; organise, service and assist the training of rural fire officers' deputies, fire party members; advise Conservator of Forests of any significant out-of-control fires; and, generally be responsible for fire suppression in its district.

In support of these duties the Minister of Forests will draw up guidelines for fire plans; assist fire authorities with instructions to landholders; assist liaison between New Zealand Forest Service, catchment authorities, Department of Lands and Survey, landholders representatives, and fire authorities in the hill and high country; provide training; organise district and national fire control meetings; arrange and maintain basic fire fighting equipment on a regional basis; develop suitable communication systems (particularly a common radio frequency); organise back-up fire-fighters and equipment (including helicopters and specialist fire fighting teams) for county fire organisations; and, regularly review legislation.

Many of the provisions for hill and high country land originated in a report (the Mt White fire report) of a study group on fire hazards of hill and high country (New Zealand Forest Service, 1974).

Rural fire issues

The liability of land occupiers for the damage from, or suppression costs of, rural fires, is a lively issue among the insurance industry, farm and forest occupiers, local rural fire authorities and the New Zealand Forest Service. The insurance industry has, in most cases, offered extensions to public liability policies to cover the costs incurred and for which liability is determined by the Forest and Rural Fires Act 1977. The amount of cover is usually determined case by case.

Following the production of a report to the Secretary of Internal Affairs (Mark, 1983) on a proper and equitable base for funding of the Fire Service, renewed impetus was given to a proposal that an appropriation by government (or the insurance industry) be made to fund rural fire suppression costs not able to be recovered from the person(s) responsible for the fire. Sections 46A and B of the Fire Service Amendment Act 1986 established a Rural Fire Fighting Fund for meeting the costs of rural fire where (a) the responsibility for fire is unknown or cannot be established and (b) all the conditions of a permit fire were complied with yet control of the fire was lost. The fund is to be established from the levy placed on all fire insurances to finance the Fire Service. These provisions do not however, mean that fire insurance premiums paid by rural property owners will be used to fund all rural fire control costs.

The common law rule that 'if a person lights a fire on his own land he must at his peril prevent it spreading to the land of his neighbour' (Kelly v. Hays, 1902) endorses the rule of Ryland v. Fletcher (1868) concerning the absolute liability for escape of things brought on to or done on the land. Farmer and insurance interests are pressing for statutory modification of the rules, but there remains the difficulty that avoidance of this responsibility may lead to irresponsible action by land occupiers, their employees or contractors.

Not all local authorities are able to fully discharge their responsibilities as

rural fire authorities under the Forest and Rural Fires Act 1977. Each authority should have appointed a Principal Fire Officer and, in most cases, other rural fire officers and fire wardens. Many of these appointments have been of persons untrained in fire prevention, fire command or fire suppression. Many have to rely on their own experience. Few opportunities are taken for training through the several courses offered by either New Zealand Forest Service or New Zealand Fire Service (Farrell, 1981).

Public awareness of fire hazards, much improved upon former years, is limited in three areas: understanding the basic structure and chain of command in county fire authorities; the recognition of fire hazards in the hill and high country; and the control of wildfires 'escaping' from land clearing operations.

The complexity of the organisation of rural fire control is exemplified by the multitude of agencies with permit-issuing responsibilities (fire authorities, catchment authorities, Conservators of Forests and, for pastoral land, Commissioners of Crown Lands, and Chief Fire Officers of fire brigades). Fire control on public and private rural land is respectively the responsibility of the New Zealand Forest Service and fire authorities. There appears to be little public understanding of the system and little knowledge by most about who is responsible for fire prevention and suppression in particular areas. Of most serious concern is the general lack of public knowledge about, or confidence in, the chain of command on a fire ground. It should be a matter of serious concern to some rural fire authorities that, in the high country, more than half of the 300 runholders at the time of the most recent TGMLI survey, considered that the fire control arrangements are 'less than good and improvements are necessary' (Kerr and Lefever, 1984).

The present rural fire legislation was derived from enactments aimed at control of forest fires. Existing legislation (Forest and Rural Fires Act, 1977) and administration, retains this predominant purpose and gives comparatively little recognition to the tussock grasslands and scrublands which are a principal fire hazard of hill and high country of the South Island.

Organisation of rural fire control

Introduction

The Minister of Forests, through the New Zealand Forest Service, is responsible for administration of the Forest and Rural Fires Act 1977 which with the Forest and Rural Fires Regulation 1979 and the Rural Fire District Regulations 1980 forms the statutory basis of safeguarding life and property by the prevention, detection, control, restriction, suppression and

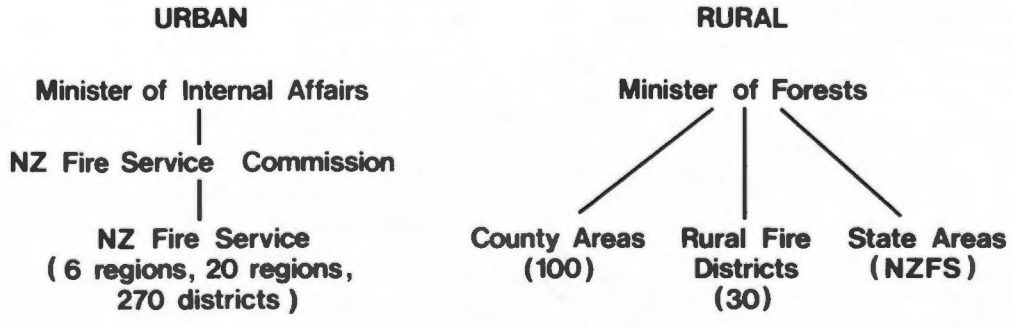


FIGURE 1: Organisation of fire control in New Zealand.

extinction of fire in forest and rural areas. The Act sets out the requirements for the several types of diverse fire authorities now in existence throughout rural New Zealand.

The responsibility for fire control in urban areas rests with the Minister of Internal Affairs through the New Zealand Fire Service Commission.

The relationship between, and the organisation of, urban and rural fire authorities is set out in Figure 1.

The organisation responsible for urban fire control (the New Zealand Fire Service) has clear objectives, a unified structure, and a well defined chain of command.

The rural fire organisation, while having a core involvement of the New Zealand Forest Service is nevertheless multifaceted in structure and is much less clear in command structure.

The only other fire control organisation separate from those outlined above is the Ministry of Transport's Rescue Fire Service based at major airports.

New Zealand Forest Service

Other than its responsibilities in the management of New Zealand forest resources the New Zealand Forest Service also has overall responsibility for rural fire control (Forest and Rural Fires Act, 1977). The day to day responsibility for fire control in other than state areas rests with local authorities (as fire authorities) or with rural fire committees (appointed for the purpose). For all State Forest Parks, and unoccupied land the Minister of Forests is solely responsible. In addition the Minister is responsible for fire control in fire safety margins of 1.5 km surrounding State areas and other forest areas.

The New Zealand Forest Service is also responsible for: the control of lighting of fires in open air (in State areas) assessing fire hazard in forests and other rural areas, warning of the danger of fires, and the declaration of, and control of, any national or regional fire emergency.

In the practical execution of its responsibilities, the New Zealand Forest Service maintains a permanent staff of specialist fire control officers at head office and at conservancy offices. These officers provide the general administration of fire control, the training of other staff, and act as fire officers. For the protection of all state areas the service maintains the equipment necessary at strategic sites. The overall average annual cost of staff, equipment and fire control operations in state areas amounts to five million dollars (A.N. Cooper pers. comm.). No rural fire insurance is carried by the state. In its role of 'supervisor' of rural fire control the New Zealand Forest Service reports an annual expenditure of $400,000 to $600,000 on 'rural fire prevention and control' (Director General of Forests, 1985 etc.). This expenditure is for grants for facilities, equipment, and training on other state areas (A.N. Cooper, pers. comm.).

New Zealand Fire Service

The New Zealand Fire Service is an integrated organisation covering 270 urban fire districts. Twenty of the fire districts are permanently staffed and the remainder volunteer brigades. The Fire Service is estimated to be responsible for the protection from fire of about 90% of the fire insurable property of New Zealand (T.A. Roberts, pers. comm.).

The New Zealand Fire Service is funded from both insurance industry and government sources at a ratio of approximately 4:1. Income of the New Zealand Fire Service Commission ($91m in 1984/85) from the insurance industry is by a levy of 6c/$100 of cover so that the total revenue from the insurance industry is 81% and the remainder 19% from government (Fire Service Ammendment Act, 1986). Formerly the insurance industry provided 72.5% 'over a reasonable

period' (Mark, 1983).

The 'incidents' attended by the New Zealand Fire Service in an average year include 20,000 fires, 15,000 non-fire incidents (flammable liquid spills, chemical or hazardous substances, rescues etc) and 10,000 false alarms. About one fifth of the fires involve trees, scrub or grass (New Zealand Fire Service, 1985). These fires are presumed to have occurred in the peri-urban or rural areas.

About 6% of county areas are provided with a fire suppression service by the New Zealand Fire Service (New Zealand Counties Association, 1985). Within county areas the New Zealand Fire Service is reported to provide a 'wholly adequate' service to about two thirds of the population, and for the remainder (about 10% of the New Zealand population) a 'less than adequate service' (New Zealand Counties Association, 1985). Nevertheless, in 1982/83, the New Zealand Fire Service attended fires outside the fire districts on over 1,000 occasions in over 60 county fire authorities and the cost of this is likely to be over $200,000 (New Zealand Counties Association, 1985).

Rural fire districts

Thirty rural fire districts are in existence for the control of fire in areas where there is a need for a special rural fire control organisation. The present rural fire districts cover six State Forest areas, one defence area, and 15 with local authority or private land owners.

Rural fire districts in local authority or private land areas are administered by Rural Fire Committees, constituted (appointed or elected) for the purpose, and representative of the area. Local authorities may be the Rural Fire Committee. Finance for Rural Fire Committees comes from an annual levy usually payable only by forest owners and not other land owners. The amount of the annual levy ($2/ha approx.) covers administrative costs only and not major fighting costs. Fire fighting costs are met from insurance, or by the person(s) responsible, or by striking a special levy, or otherwise born directly by those affected (S 46 of the Act).

County fire authorities

The fire authority in each county area is the County Council, Borough Council, or District Council having territorial jurisdiction. There are 100 county fire authorities in rural areas. Each County is responsible, among its many other duties, for the promotion and carrying out of fire control measures and for the preparation of a fire plan.

Two thirds of all counties provide a rural fire suppression service in some part of their district. The remainder consider they have no commitments under the Forest and Rural Fires Act because they have, it seems, no fire risk. The proportion of county districts where the County acts as the fire authority varies from 100% to less than 10% with an average of about 66%. The fire authority for the remainder of the area is either the New Zealand Forest Service (for State Areas - an average 20% of total area of counties), Rural Fire Committees (5%), New Zealand Fire Service (6%) or other e.g. catchment authorities, defence areas (2%) (New Zealand Counties Association, 1985).

The cost of rural fire suppression carried out by County Councils, in 1982/83, amounted to almost $600,000 of which the major part were extra-ordinary costs (including voluntary contributions) and the remainder 'standing costs' of equipment and labour. Most counties recover these costs from general revenue but some endeavour to recover at least some of the costs from the persons responsible for the fire (New Zealand Counties Association, 1985).

Finance

The costs of fire control in urban areas falls largely on the insurance industry with about one fifth from the State. In rural State areas the fire control costs are met by the State alone (and

the risks are uninsured). In other rural areas the community (through rates) or the individual property owner (usually insured) pays. With the advent of a rural fire fighting fund the costs of rural fire from 'unknown causes' will be met.

It remains an issue whether the insurance industry, as in the case of urban areas, should meet a proportion of the costs of rural fire control organisations. A model for this is the County Fire Services of South Australia in which the State Government and the insurance industry share the costs equally (South Australia Country Fire Services Board, 1983). It is expected that, before such an arrangement would be considered for New Zealand, a less complex, possibly single purpose organisation would need to be established. For New Zealand the benefits may not outweigh the costs - but further study should clarify the issues.

Fire permits

As provided for in the Forest and Rural Fires Act 1977, permits are often required to 'light fires in the open air'.

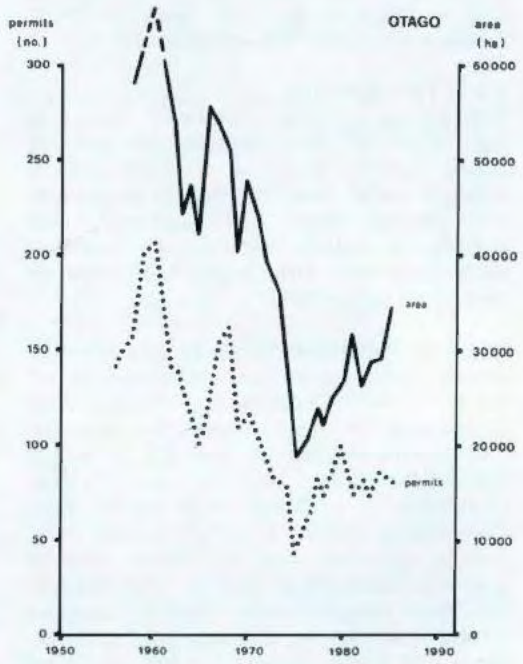
In an open fire season (unrestricted) a permit under the Forest and Rural Fires Act (1977), is required only in State areas (National Parks, State Forests, reserves, etc.), and forest areas (including fire safety margins).

In a restricted fire season a permit from a Fire Officer to light a fire in the open air (but not a fireplace, incinerator, barbeque, etc.) is always required.

When, in extreme fire hazard conditions, a fire authority has declared a prohibited fire season all current permits are suspensed, and Special Fire Permits may only be issued by the Principal Fire Officer or the Conservator of Forests.

Fire permits are required to be in writing, and detail the location of property, material to be burnt, date of the proposed fire and include any general and specific conditions applicable. Fire permits do not relieve any person from liabilities arising from exercising the permit.

Regulations pursuant to the Soil Conservation and River Control Act (1941) enable catchment authorities (for the purposes of soil conservation) to control the burning of vegetation. This is usually achieved by a by-law which encompasses a permit issuing system. The type of land covered by burning by-laws invariably includes hill and high country land prone to erosion and seasonally subject to fire hazards. Before catchment authorities issue burning permits, an inspection of the site is made (normally by an experienced staff member) and if a recommendation to issue a permit is made, it is usually accompanied by recommended special conditions. Copies of the permit are sent to the rural fire authority and in the case of pastoral leases, the Commissioner of Crown lands.



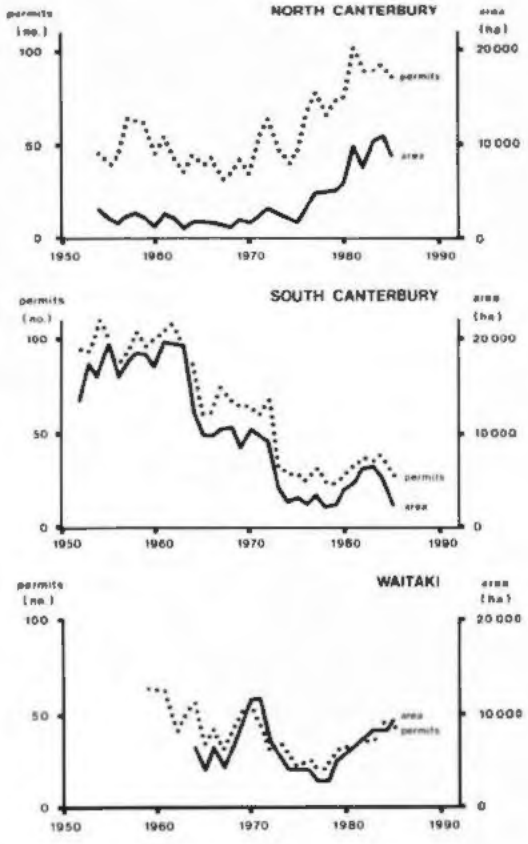


FIGURE 2: Number and area of permits to burn.

The numbers and area of permits to burn issued over recent years by four catchment authorities on the eastern South Island which have large areas of hill and high country land are set out in Figure 2. Some variation in the policies within and between individual authorities is apparent. Burning on pastoral land is prohibited without the prior written consent of the Commissioner of Crown lands (Land Act 1948, S 106). Catchment authorities' bylaws have displaced the need for a separate permit from the Commissioner of Crown land. There is, however, some opinion that the 'delegation' or 'entrustment' to catchment authorities is ultra vires.

If the fire permit is for an area within a fire safety margin (1.5 km) of a State area then the permit requires signed approval of the relevant State rural fire office. Similarly, the signed approval of the local authority rural fire officer is required in a restricted fire season.

It is important to restate that all permits, irrespective of their origin, are suspended when a relevant fire authority or the Conservator of Forests declares a prohibited fire season over all or part of its district. The need for strict supervision of fire permits is emphasised by the extraordinary large number of wildfires that had their origin in land clearing operations. Furthermore, in the high country of the South Island, where catchment authorities have played the major role as permit issuing authorities, almost half of the uncontrolled fires reported were escapes from permitted fires, and a further one third were deliberately lit without a permit.

Obviously there is an interrelationship between perception of fire hazard and the issuing of permits to burn. The knowledge of actual and potential fire hazard must, of necessity, be matched with the management of fire by both permittee and permittor. It is unfortunate that in some districts there are a confusing number of permit issuing authorities. In consequence the role of each is diminished and often unknown. Some reform is overdue.

Incidences of fire

Sources of wild fires

The reported incidences and causes of 'wildfires' (i.e. out of control fires) in rural New Zealand over recent years is shown in Table 1.

This information has been compiled from returns to the Chief Fire Control Officer, New Zealand Forest Service, by Conservancies, Rural Fire District Committee and County Fire Authorities. The basis of recording wildfires differs slightly between organisations as does the standard of reporting. Nevertheless

TABLE 1: Wildfires in rural New Zealand.

Cause	80/81	81/82	82/83	83/84	84/85
Road traffic	-	24	64	34	50
Tractors and motor vehicles	-	62	77	34	94
Tramways and railways	-	19	20	14	18
Hunters	-	10		5	17
Picnics/campsites	-	15	37	16	26
Smokers	-	43	34	25	40
Landclearing	-	232	300	168	297
Incendiary	-	67	43	65	90
Logging/milling	-	37	36	35	28
Other	-	0	156	11	0
Unknown	-	171	173	130	326
Total number of fires	584	680	940	537	986

the information presented is considered to reflect the incidences of wildfires in New Zealand over recent years.

A large proportion of wildfires have been the result of an escape from 'landclearing operations' (31-34%) and from 'unknown' causes (18-25%). This pattern is general for all three classes of fire authorities.

The 986 wildfires in rural areas reported in 1984/85 burnt over 10 000 hectares of grassland, over 28 000 hectares of scrubland, and over 200 hectares of forest. The 1984/85 fire season was regarded as drier than usual with more than an average number of reported fires (notably from unknown causes) including an especially large fire in a Defence Area fire district.

South Island high country

Information about uncontrolled fires in the high country of the South Island and investigated by catchment authorities from 1956-82 has been assembled (Paulin, 1985) and is summarised in Table 2.

Almost three quarters of the wildfires investigated in the South Island high country had their origins in 'land clearing' operations - a high proportion of which were unauthorised. Nearly all escaped permit fires occurred in north-west winds which prevail in the late winter-early spring period most favoured for burning.

Fire hazard

General

From the evidence of the incidence of uncontrolled fire, the risk of uncontrolled fires in rural areas arises from a combination of factors, principally people, fuel and climate. Noting that the main cause of wildfires throughout the country are actions by people (chiefly carrying out 'land clearing' operations), there is obviously a need for improved care and understanding by the fire permit issuing authorities (and people generally) about the risks of uncontrolled fires and the likely cause of damage.

Fire weather

The New Zealand Forest Service has

TABLE 2: Uncontrolled fires investigated by South Island Catchment Authorities, 1952-82.

Cause	
Escaped from permit fire	35
Deliberately lit without permit	29
Accidental	5
Recreational users	5
Unknown	7
Army	2
Vehicles	3
	86

Time of year

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4	8	1	-	-	-	-	20	24	19	2	1

Weather conditions

North west	61
Suitable	25

Predominant vegetation

Scrub	36 (includes some beech forest)
Tussock	50

Control

None - fire burnt out	33
NZFS/County/Brigade	18
Runholders & neighbours & locals	35

SOURCE: Paulin, 1985.

adopted a Canadian system of fire danger rating - the Fire Weather Index (FWI). The index is based on mid-day weather readings and represents components of the moisture content of forest fuels, potentiality for the spread of fire, and the amount of available fuel (Van Wagner, 1974; Valentine, 1978).

Temperature, rain and wind are obviously of major significance to the fire weather index. Taken separately, each of the components has only limited significance to the final index, but together (e.g. windy conditions at high temperatures in a drought) can, if there is available fuel, generate conditions of extreme fire hazard. Some idea of the areas of the South Island most likely to experience high fire risk can be gained from Figure 3 showing average temperature, rainfall, and wind.

Fuel

The type, cover and biomass of vegetation of the South Island has been assessed to determine the nature and amount of fuel and its relative fire hazard. The vegetation recorded in the mapping units of the New Zealand Land Resource Inventory (Hunter and Blaschke, 1986) comprises 44 classes arranged in five groups: grassland, cropland, scrubland, forest, and

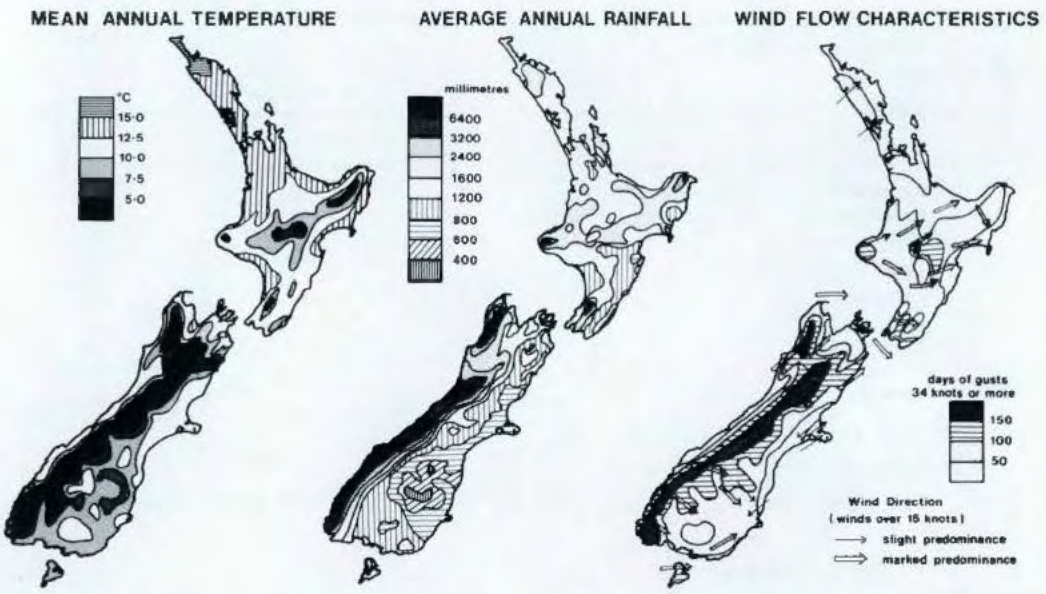


FIGURE 3: Mean annual temperature, average rainfall, and wind flow characteristics.

miscellaneous. Each class (when recorded as the dominant vegetation) has been categorised according to its likelihood of supporting an uncontrolled fire. Vegetation considered unlikely to support fire is high producing pasture and cropland. All other vegetation is ranked as 'burnable'. It is recognised that some maturing crops can be a seasonal fire hazard but the overall hazard of cropland is considered generally slight and normally readily contained.

The burnable vegetation has been grouped into four categories based on the amount of fuel (above ground biomass) viz forest (200-600 t/ha), scrub 50-150 t/ha), 'tall' grassland (15-60 t/ha), and 'short' grassland (10-20 t/ha).

Hazard

Published maps on rainfall, temperatures, and wind (Wards, 1976) do not by themselves provide a comprehensive picture of environmental fire hazard chiefly because of the seasonal effects of rainfall and temperature, and the immediate effect of wind.

Soil moisture deficit maps (Coulter, 1973; Salinger, 1985) give a more useful indication of the geographic extent of fire hazard. The genetic classification for New Zealand soils (Taylor and Pohlen, 1962; New Zealand Soil Bureau, 1986) with its grouping of soils (especially zonal soils) into soil moisture classes is considered to be a satisfactory basis for the delineation of fire hazard because these classes reflect both rainfall and soil moisture conditions for plant growth.

The areas of three broad classes (low, medium, high) of environmental fire hazard for the South Island have been identified from the soil survey information described above. The limit of the 'high' hazard broadly corresponds to the 800 m rainfall isohyet and includes coastal Marlborough and Canterbury and inland Waitaki and Central Otago. 'Low' hazard areas include the hygrous - hygrous lowland yellow-brown earths and podzolised soils. These soils are above field capacity all year. The 'low' hazard class receives generally more than 2000 mm of rainfall and is predominantly on

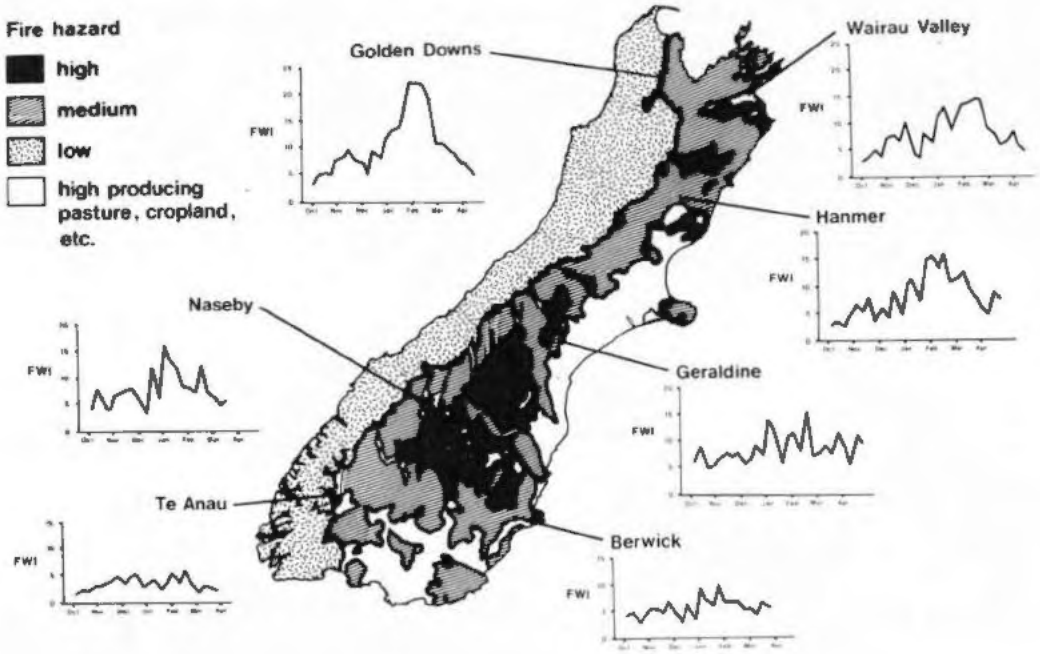


FIGURE 4: Environmental fire hazard and fire weather indices.

the west of the island.

The high and moderate hazard classes include districts most susceptible to desiccation and gusty north-westerly winds. Because the suggested zonation represents only the overall geographical dimension of fire hazard it does not reflect the marked seasonal changes in fire hazard that occur. Fire weather index information for five fire seasons has been averaged for seven stations. Such information indicates the seasonal pattern within stations and the wide differences between stations both seasonally and geographically.

A map depicting areas of the environmental fire hazard classes with graphs of seasonal changes in fire weather indices is offered as a pictorial representation of fire hazard (Figure 4).

The nature and area of fuel in the various fire hazard area has been calculated and shown in Table 3.

For those counties with large areas of forest or tall tussock grassland lying within high or medium fire hazard areas, the problems of fire prevention are likely to be greatest. This is compounded in areas where seasonal fire weather indices are invariably high or extreme for long periods. In addition, for those localities when there are concentrations of people living, working or travelling the risks will be accentuated. Fire prevention in these areas through a wide range of measures (permits, limiting of specific activities, public education etc.) and increased fire suppression will need to be of a correspondingly high standard.

Discussion

The management of fire in rural areas of New Zealand generally, and in the hill and high country particularly, is achieved through a complex set of organisations and procedures. These arrangements have been built up over many years to serve the needs of the time. Rural fires, especially wild fires, are often regarded as having actual or potential consequences to life, property,

TABLE 3: Areas of fire hazard and types of fuel, South Island.

Hazard	Fuel	Area (ha)	Total
High	forest	33 000	
	scrub	47 000	
	tall grassland	116 000	
	short grassland	1 502 600	
	pasture*	1 006 100	
			2 706 500
Medium	dense forest	2 800	
	scrub	28 800	
	tall grassland	49 800	
	short grassland	438 800	
	pasture*	1 651 300	
			6 253 100
Low	forest	3 150 700	
	scrub	475 700	
	tall grassland	714 900	
	short grassland	734 700	
	pasture*	424 900	
			5 504 900

* High producing pasture unlikely to support fire (unclassified on map of fire hazard classes).

forest, scrubland and grassland (Campbell, 1945; Department of Lands and Survey, 1968; O'Connor, 1974; Kidd, 1981). There is, therefore, a need to maintain efficient fire prevention and control measures.

The deleterious effect of fire in the removal of native forests and the modification of tussock grasslands has been noted (Walker, 1876; Buchanan, 1865; Reed, 1964; Molloy, 1968; Connor and McRae, 1968). The response from these and other observations has been the purposeful control of fire for the protection of indigenous vegetation. Similarly the establishment of large exotic forests from the 1930s onward (and the consequent losses from fire) has led to the adoption of forest fire prevention and suppression methods to protect valuable growing assets. These two examples demonstrate the apparent (but seldom stated) twin fire control objectives of conservation of nature and the protection of productive assets.

The organisation and funding of rural fire control is likely to continue to be a lively issue in the future. The reorganisation (and redefinition of objectives) of elements of the New Zealand Forest Service and Department of Lands and Survey, together with increasing constraints of public expenditure, will inevitably put funding and staffing strains on the present organisation of rural fire control. It is understood that the Minister of Conservation, and the Forest Corporation will become fire authorities for their respective responsibility with the Ministry of Forests administering the Forest and Rural Fires Act (1977) on behalf of the Minister (A.N. Cooper pers. comm.). There seems to be some merit in a suggested Rural Fire Authorities Association. The outcome is unclear, but if administrative changes are made it is hoped they will be positive reforms with clear, but comprehensive, objectives embracing the protection of life, property, and other assets of this country.

Acknowledgements
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The influence of science on the use of tussock grasslands

K. F. O'Connor

How science is related to use

An oral version of this paper was presented to the fifth Hellaby Seminar (Baylis, 1984), held at Otago Museum in October, 1985. It was then titled, "Using our tussock grasslands - how the future might learn from the past." It was prepared in response to an invitation to "review the whole history of use and abuse of our tussock grasslands." I had felt constantly challenged by this invitation during 1985 for I was then involved in a series of exercises, analysing and reflecting on research, teaching and practice in ecology. During one lovely week in a Hudson Valley spring I had been engaged at New York Botanical Garden's new Institute of Ecosystem Studies with about 50 ecologists, mostly from North America and Europe, to examine the future of ecosystem science. For most of 1985 I had been busy with my colleagues at Lincoln College devising and building the ecologic base for a new Bachelor's degree programme in Parks and Recreation Management. Meanwhile New Zealand natural resources had been launched down the slipway of economic theory into the most intensive maelstrom of public administration reform that we had seen for 100 years. Out of this reform new government agencies, with new functions and responsibilities would emerge. My concern was that these new agencies should be ecologically sound and relevant to the real world. If the going was to be tough, the economics were going to be highly dependent on the quality of ecology that underpinned them.

I was involved in each of these activities, in different ways stimulated to focus on scientific research, on land use and administration, and on the extension by which the former is believed to influence the latter. It was a year of instability and ferment. Produce prices, interest rates, the conventions and assumptions of resource administration, everything was on the move. By year's end it had grown increasingly clear that tussock grasslands, both in their own right and as part of the New Zealand natural environment, were at some new flexure in history.

Confronted with the future, called upon to decide or advise for the future, many of us instinctively look back to see what we might learn from the past. We know deep down that history never repeats itself, exactly. Nevertheless we look for parallels, analogies, conscious in some way that experience is not totally sterile. If we think about this very human activity called science, and not simply work or play as technocrats, we know that science involves a search for order, for consistency. We learn that it depends for its progress on a definable logic, even a logic of rejection of what is held, of a kind of revolution, of innovation of ideas. The same Karl Popper who has prescribed for us "The Logic of Scientific Discovery" also warns us of "The Poverty of Historicism." We are warned against theories of historicist determinism at the same time as he encourages us to trace the pathways of scientific ideas through their context of social and

economic history. We are to look back but not as one who looks through a tunnel.

The braiding of history

Karl Popper (1959) prefaced the first English edition of "The Logic of Scientific Discovery" with a quotation from that most quotable person who remains so little read, Lord Acton. He wrote: "There is nothing more necessary to the man of science than its history and the logic of discovery...: the way error is detected, the use of hypothesis, of imagination, the mode of testing". If as scientists we need to know how we came to know what we now know, so also as users of land we need to know how we came to do as we do. The history of use of tussock grasslands demands for its interpretation a history of our economy and political administration. For the future to profit from such history, it requires also an entwined history of our understanding of our tussock grasslands, their condition, and the forces at work on them. Our uses of our natural resources grew from our perception of them at particular times, for natural resources are elements of the environment on which we confer utility. It is from such beginnings in perception that with progressive enumeration and refinement, with definition and distinction, with methodic doubt and the formulation and testing of hypotheses, that we grow in scientific understanding. This process we call science is no one's monopoly. Like shearing sheep or making pie crust, it requires the development of skill. Like work of any sort, it is a very human activity.

As tussock grassland scientists then, we might benefit from attention to Acton's dictum. As citizen scientists we might find in our understanding of this four-strand braided history of land use, economy, science and public administration, an explanation of why we have not yet been able to change our world. I believe we can also find grounds for hope that we can be of use to our society and to our land. As tussock grasslands users, whether for work or play, we may learn from this analysis of our own history some of the powers and limitations of science. Thereby we may be able to accommodate science more congenially and more fruitfully.

In one of the more important papers (O'Connor et al., 1986) in which I have written on the history of land use, we focused on the characteristic slowness with which land use and land administration responded to changes in economic and ecologic conditions at three different phases of our pastoral history. Some unfortunate consequences appear to have ensued, not least the costly application of corrective policies too late to have preventive effect and often too little to be remedial.

Policies, mythologies and science

It is becoming increasingly recognised that we should learn the importance of myths, and of changes in myths, statements of belief by societies, about ourselves or our world. Political decision-making gives implicit or explicit attention to our myths, for myths include or reflect our values, what we most want. Likewise the pattern of resource use which at the same time is both substrate and expression of our culture, is animated and sustained by our traditional myths. It is therefore of special interest to me as a scientist to discern the influence of scientific activity on our myths about tussock grasslands and our use of them. In present times, I have wondered whether current mythologies on which substantial changes in land administration are founded, are any better grounded in scientific understanding of reality than were the myths that have been believed in by land users and land administrators in the past. I am conscious in expressing this doubt that I might seem to be passing judgment on current changes. In fact I withhold such judgment until the changes take clearer form. Meanwhile I have warned appropriate ministers of particular areas in which I see current myth deviating from reality.

By the time this is published we shall know better the shape of future administration.

Past myths reflect a wide range of attitudes from idealistic admiration of nature or pragmatic optimism for maintenance of the pastoral status quo to zealotry for land-healing and land use reform. These myths are illustrated by a string of captions and slogans as familiar as the cry of the kea: "tawny uplands of the south", Samuel Butler's "burn you must", "mustering the back basins", "down to the sea in slips", "the country's in great heart", "down from the misty gorges" and "the people's heritage for outdoor recreation". Tussock tattle to the cynic it may be but complex and true mountain mythology it remains for an increasingly complex society.

My purpose in listing some of these captions or slogans is not to analyse them, still less to criticise them. It is simply to illustrate their variety and to show the importance of the attitudes behind them. They are called captions or slogans because they are headings or rallying cries, evoking support or loyalty for a way of life or a particular cause. At least some of us want to see some such values enshrined in public policy. Each of them can be recognised to reflect a continuing body of belief in pastoralism in one form or another, or fear of massive erosion, or joy in the poetry of wind in tall tussock. Such fears, joys and beliefs are not readily analysed, least of all from their catch-cries. Some of them are comparatively recent. Even those which are old are not immune to change and many of the changes in myths have been quite subtle. Scientific activity of one kind or another has often been associated with such changes in mythology. The degree and direction of such changes do not, however, appear to be closely related to the quality and cogency of the science.

Common core of science and planning

If we are to understand the relationships between scientific activity and our myths about tussock grasslands and their use, we have first to appreciate that scientific activity has had common origins with our land use mythology. Second, we should also recognise that the two kinds of human activities, science of nature and use of nature, may diverge or may remain in close harmony. Once they have diverged, we may observe that other forces may keep them apart or may bring them together. Third, science and land use mythology affect one another, often in very complex ways. Indeed as Hayward and Burton (1978) have illustrated concerning the science of forest influence on stream flow in both Europe and North America, so too in other fields of science with land use significance: the new myths and the new public policy may precede the scientific activity that is later credited with justifying the policy! Of course, scientific research would hoe an even harder row should it fail to justify such policy! A scientist may in fact deserve public gratitude but he or she may suffer sharp financial cuts as reward for shattering the holy icons of official policy. I shall return to a more detailed examination of these three points. First, a warning about the nature of scientific story-telling.

It is very easy in discussing these matters to slip into pretentiousness about science. Only in some dull image could even the finest of scientific activity in the tussock grasslands be seen as classic science. Yet what is known as the logic of discovery, the hypothetico-deductive system, can be discerned therein in all its applied, earthy and useful ramifications, just as it can be seen in rarefied physics. Just what is involved in the "hypothetico-deductive system" or "scientific method" scientists are notoriously poor at explaining. "Ask a scientist what he conceives the scientific method to be," writes Peter Medawar (1984) "and he will adopt an expression that is at once solemn and shifty-eyed: solemn, because he feels he ought to declare an opinion;

shifty-eyed, because he is wondering how to conceal the fact that he has nothing to declare." As a distinguished biologist, Medawar knew only too well that "biologists work very close to the frontier between bewilderment and understanding." What Medawar recognised was that

> "the activity which is characteristically scientific begins with an explanatory conjecture which at once becomes the subject of an energetic critical analysis. It is an instance of a far more general stratagem that underlies every enlargement of general understanding and every new solution of the problem of finding our way about the world."

"Having an idea," the formulation of a hypothesis, is a very human activity, in many ways as creative as an artistic act. No amount of fact-gathering or measurement, however sophisticated, will make an activity scientific if it lacks the spark of the testable explanatory idea. The distinguishing mark of the scientific process is in the regulation and control of hypotheses, a process considered by Medawar to be more usefully described as cybernetic rather than one of formal logic. "The adjustment and reformulation of hypotheses through an examination of their deductive consequences is simply another setting for the ubiquitous phenomenon of negative feedback" (loc. cit. p.135). The plain truth from Medawar is that scientists tell stories which are then scrupulously tested to see if they are stories about real life.

Not only is science a special kind of story-telling but, as can be recognised from the earlier quotation from Medawar, it is an instance of a more general human behaviour, the enlargement of understanding, "finding our way about the world". In this are the common elements of the use of natural resources and the science of nature. Whereas the scientist is telling a story which he then tests to see if it is about real life, the land user tells himself a story about the utility of nature and then sets about demonstrating it. If the scientist finds his story, his explanatory conjecture, doesn't work, or only fits some of the data, he modifies his hypothesis or rejects it altogether, if he is a thorough scientist. In some cases the process of rejection goes deeper. If the scientific community comes to reject one time-honoured theory in favour of another incompatible with it, with consequent shift in the problems available for scientific scrutiny, in what problems were considered admissible and what kinds of solutions are considered legitimate, and if we have a fundamental transformation of scientific imagination itself, then we have what Thomas Kuhn (1970) has described as the essentials of a scientific revolution. Such revolutions are not as frequent as one might hope.

If the land user finds his story about the usefulness of land doesn't work out, or works only for a time, he also changes his story, if he can. If the land-using community comes to reject the time-honoured utility theory in favour of another incompatible with it, with consequent shifts in inputs, technologies and outputs and with a fundamental transformation of the whole land use imagination, then we can see the essentials of a land use revolution. They are not very common, either.

Insofar as the "science story" and the "utility story" hang together, science and land use remain in harmony, even though both may change. The science story may promote the utility theory and the land use promote the science. If the two kinds of stories come apart, or if they never came together in the first place, they have no mutual influence. Such situations can exist. They may be even more common than we care to admit. Science is neither essential nor compelling. In real life, new story-tellers may be summoned in either science or land use if society or its rulers are dissatisfied with disharmony between the two kinds of stories.

Neither old story-tellers or new story-tellers however, have any guarantee that they will be true about the real world. Indeed, the best that either kind of story-teller can hope for is that his story will be credible for a time, that his myths ring true. As Medawar has pointed out, we are indebted to Claude Bernard, the French physiologist of the seventeenth century for the first masterly exposition of doubt. We can be confident in planning land use and in science that eventually our solutions will be found wrong. It is a great irony that the stories of science which alone make general use of mathematical probability are undermined in time by the force of the very doubt which they nurtured within them.

What only too often happens is that the science stories and the utility stories come apart with a change in economic or ecologic circumstances. The rulers of society may not bother at this divergence or discrepancy. In such circumstances, science may be well and truly neglected. In other conditions the existing myths and the forces of public policy may influence the story-telling on either side. The utility story-telling may be larded with hidden subsidies. The science story-telling may be distorted with priorities, generally under the name of science policies, often concerned with those current magic phrases, "R & D" and "information transfer". In either case, the myths may be held more strongly and firmly and at the same time be edging further and further from the real world. It is a brave man or woman as honest and thorough scientist who then announces that the emperor has no clothes!

Questioning a naive prejudice

Seen in this light, scientific activity and land use planning activity have a great deal in common, whether conducted by individuals or by corporate persons. The varied situations and circumstances in which such common activities occur reveal among public and scientists alike a very widespread naivety. This naivety would suggest that once problems are understood and solved by science, the solution is soon applied by land administrators and land managers. This suggestion fails to take account of the wealth of factors which keep the two kinds of stories apart, but it has nevertheless led to some common and unfortunate corollaries. If it is believed that scientists' solutions to problems are quickly applied by managers, it will also be believed that any failure to apply solutions must come from insufficient research, from ineffective communication or from research irrelevance. In fact not only are the corollaries incomplete, but they rest on a quite unvalidated premise. In many cases in our tussock grassland history we shall find that discovered solutions to perceived problems remain for managers and land administrators what Johnston (1972) has called "blocked choices". Many of these blockages seem to affect the "feasibility" of solutions. It shall be part of my theme that our failure to perceive choices as open to us may often derive from our social structures for resource management and for science. It is my particular interest to examine what have been our social structures for science, who have been encouraged to behave as scientists, what kinds of issues have they been stimulated to address, and to what extent have such issues been narrowed by their apparent relevance to established utility stories. I should like to discern to what degree have the "utility stories" influenced the "science stories" and to what extent has science influenced land use.

Outline of approach to topic

I shall attempt to summarise the three major phases of tussock grassland pastoral use history and to characterise the role of scientific activity in each phase, especially examining the role of science in altering or reinforcing existing dominant myths. The burden of this part of the essay is that in all three phases of our pastoral history, scientific activity and technological innovation have been apparently closely

attended to by pastoral users, but science has itself had generally slow and limited effect on pastoral mythology, with least effect on land use administration. Possible reasons for this kind of situation are examined and its implications for future resource administration and for science promotion are expounded.

It is my thesis that scientific discovery has had notably small and slow influence on the uses of tussock grasslands and their administration in the past. If conditions in the future are similar to those of the past I expect this sad and costly situation to continue. For this reason I am anxious to understand how past conditions have made scientific activity so unfruitful in public policy.

It is my further hypothesis that the small and slow influence of scientific activity on fundamental features of public policy of tussock grassland may derive from the organisational separation of scientific activity and public policy development which has existed except for a very short period at the beginning of pastoral history. It is not possible to examine this hypothesis thoroughly but sufficient indications are revealed that would warrant a radically different organisational approach for the future.

Science and pastoral establishment

The extent of pastoral occupation

Pastoral occupation of open country in both main islands of New Zealand was rapid (O'Connor and Kerr, 1978). Most of the eastern country grasslands were in sheep runs or cattle runs by the late 1850s. The last of the Canterbury zone runs and of the Southern Lakes runs were established by the early 1860s. The land thus first taken for pastoralism in the high country has generally remained longest in dominant pastoral use.

Expansion into the subalpine grassland above forests on and west of the Main Divide continued into the 1880s and 1890s after there were no further lower grasslands to be taken up or to be made by firing forest or flaxland. Retreat from such tentative high altitude, high rainfall locations was not complete in some parts of Westland and Otago until the late 1930s. Net pastoral retreat still continues, somewhat erratically up to the present time. We now call it "land retirement" or "destocking and land surrender".

Since this establishment phase identified the pastoral high country geographically, there are six facts which I should make clear lest confusion arise concerning changes in areas. First, what was effectively occupied pastoral land has not remained constant in area from the time when the runs were first taken up. Second, there are some instances even in recent years, where land which for many years remained unstocked, except perhaps with feral animals, has subsequently been resumed into pastoral use. Third, as was pointed out from analysis of data from different survey records (O'Connor, 1977), the net reduction over recent decades in area stocked was probably as much through pastoral management adjustments as it was through official land retirement programmes (cf. Kerr and Douglas, 1984). Fourth, many of the open mountain areas now in National Parks or Forest Parks were at one time pastorally occupied. Fifth, the area of pastoral licences or leases has never been coincident with "pastoral high country". (Pastoral leases have been issued for other kinds of terrain; and other kinds of tenure, including freehold and lease of endowment lands, have existed in the pastoral high country.) Sixth, the decline in number of pastoral leases in recent years has principally been through the reclassification of land as farm land and the issuance of renewable leases in their stead.

Despite these features, we can fairly but summarily assert that pastoral occupation was indeed thorough, that it was clearly a dominant use, and that once firmly established, its principally leasehold occupation of tussock

mountain lands has been maintained over substantially the same territory for more than a century.

How did this pastoral establishment phase define itself historically? When was it completed? What were its pastoral myths and how did contemporary science affect them? I have elsewhere defined the establishment phase ecologically as the eruption of domestic livestock numbers on high country runs (O'Connor, 1980). In this I follow by analogy the interpretations of wild animal populations of Riney (1964), prompted by Holloway (1950) with deer and made explicit by Caughley (1970) with tahr. The eruptive growth of domestic livestock on natural grasslands of South Island open country is indicated in Figure 1 compiled from statistical data for all of South Island excluding Westland. The 1850s and the 1860s were decades of continuous growth in livestock numbers. The 1870s were erratic in livestock growth as well as being unpredictable in private and public finance (Gardner, 1981). Total livestock units exceeded 10.7 million as early as 1874, 11.3 million in 1878, before declining temporarily to 10.5 million in 1881.

The 1850s to 1870s was a period of pastoral exploitation of natural grasslands on plains, downs and mountains throughout the South Island. Until the late 1870s, minimal contribution to livestock feeding was made from sown pastures and crops on cultivated ground. So much can be interpreted from Evans (1956) and other primary sources collated in Figure 2, in the low ratio of sown pasture hectares per 1000 sheep. I have argued elsewhere (O'Connor, 1982) that the peak of livestock numbers on any territory of unimproved grasslands was generally attained by about 20 years from colonisation of such lands. This peak can be considered to mark the end of the eruptive phase. For much of the high country, however, there was

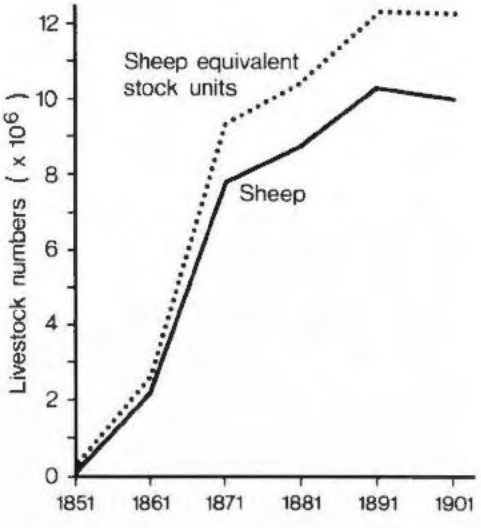

FIGURE 1: The growth of sheep and sheep equivalent livestock numbers during the 19th century pastoral establishment phase in South Island, New Zealand (excluding Westland), shown at 10-year intervals.

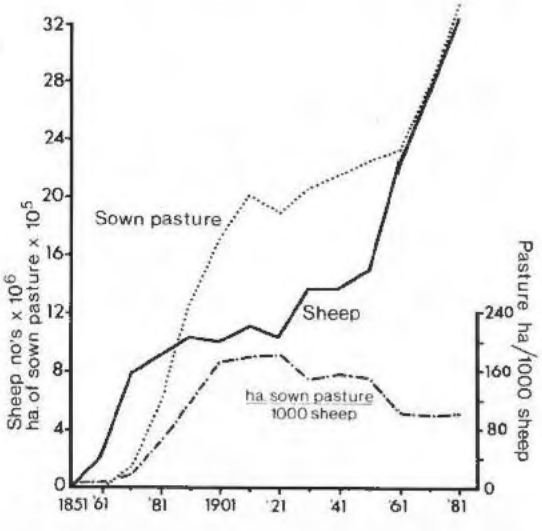

FIGURE 2: Changes in areas of sown pastures, in sheep numbers, and in ratio of sown pasture, hectares per thousand sheep, for South Island, New Zealand (excluding Westland) at 10-year intervals from 1851.

almost a decade lag behind the lowlands in both the beginning and end of this eruptive phase. Peak livestock numbers may have been reached for early established high country runs such as Morven Hills, by the mid 1870s (Duff, 1978). For some other high country areas, the early peak of livestock numbers would not have been approached until the 1880s. Gardner (1981) has assessed that by the late 1870s, the New Zealand economy was saturated with debt. By the same time the natural grasslands must have been close to saturation with sheep.

Early stories of science and utility

What kinds of stories did scientists and resource users tell of those early natural grasslands? First it should be made clear that stories about soil erosion were not a feature of their early repertoire. Such stories did not appear until the 1930s (O'Connor, 1980; McCaskill, 1973). Stories about grassland vegetation, the suitability and unsuitability of this "wasteland" for pasturage and the need for burning of grassland and shrubland are features of both lay and official literature of the time e.g. Butler (1863), Thomson (1859a,b); Garvie (1859); Torlesse (Maling, 1958). Stories of concern about excessive and imprudent burning appear from the same period (Garvie, 1859; Buchanan, 1868).

The interactive impacts of regular burning and increasing livestock loads in the eruptive phase of pastoralism have been illustrated elsewhere (O'Connor, 1982). Whitehouse (1984) has indicated that most of the old photographs with which modern or intermediate scenes might be compared to assess early pastoral impact on vegetative cover were taken after 1880. As Relph (1958) concluded concerning the Castle Hill Basin, vegetation cover was not more extensive in 1882 than it was in the 1950s. If man caused denudation in cover at higher altitudes in that district, then it occurred before 1882.

On the plains of Canterbury, there is abundant evidence that there were substantial changes in vegetation physiognomy in the first two or three decades of pastoral settlement. Torlesse (Maling, 1958; Gillespie, 1958) described the extensive swampy flaxlands of the heavier soils of these plains as well as the scrub and grassland on drier soils. Gillespie (1958) and Gardner (1971) both illustrate such formations, sometimes from early photographs of Dr Barker. In the vicinity of Ashburton Forks, Kennaway (1874) described what seems to be Chionochloa flavescens grassland at an early campsite. Roberts (1895), in his diary account of an overland journey from Nelson to Southland in 1856, gives perceptive descriptions of the vegetation for several localities in North Canterbury, Mid Canterbury and Waimate, North Otago, the neighbourhood of Dunedin, South Otago and Southland. The occurrences of swamp, low altitude snowgrass, scrub and bush remnants are frequently noted.

It was for some of these southern districts listed, as well as their immediate uplands, that Buchanan (1868) wrote with such clarity and understanding of the recent forest past of Otago:

> "It is evident that at no distant time the greater part of the Province was covered with forest. On many of the grass ridges may still be seen the remains of large trees; and over large areas, the surface is dotted with the little hillocks and corresponding hollows produced by the upturned roots of trees, which have been blown over, generally in the line of the prevailing winds, after their destruction by fire, and no doubt there have been many denudations and reproductions of bush.
>
> At the beginning of the settlement, large tracts of the Province were being reclothed with bush, but as the country was opened for cattle and sheep runs, this new growth was again burnt off, and a luxuriant growth of native grasses appeared, without seed being sown.

> In 1852, much of what is now the finest grass country, on the Clutha, Tuapeka, Waitahuna, Pomahaka, and Wyndham districts was covered with an impenetrable growth of shrubs and young trees.
>
> The further extension of bush, therefore, has been arrested by settlement; and the still existing portion will gradually disappear, in the process of clearing land for cultivation, and for use as fuel, building and fencing".

It is from passages like this that we can form a better appreciation of what was early scientific observation and concern in New Zealand pastoral country. It also assists us to see how early vegetation conditions could have been misrepresented during the years of the second pastoral phase, from about 1880 to 1950. The concerns of such early naturalists as Buchanan in Otago, Monro and Travers in Nelson and Marlborough, Travers and the Armstrongs in Canterbury, Colenso and Kirk in North Island, were generally as shown here, about the conversion of scrub, bush and flax into grass pasturage, or about the utility of the vegetation generally and the adaptation of introduced species. The paucity of grass species and their thinness on the ground were noted for some particular locations, such as the most arid terraces in Central Otago (Buchanan, 1868) and some alpine areas in the northern part of the Island (Monro, 1868). These features aside, the condition of the natural grasslands themselves did not attract general concern before 1880. The noteworthy exceptions are in the anxiety expressed by Garvie (1859) and by Buchanan (1868) concerning imprudent burning. Neither condemns burning altogether. As pointed out by Garvie, prudent repeated burning could be used to destroy scrub and timely burning could be used to convert snowgrass into finer pasture. Buchanan (1868) however, is explicit in his warning against "repeated burning of the pasture in arid districts, which is so frequently practised".

In effect, apart from the Otago observations of such survey personnel as Garvie (1859) and Buchanan (1868) and amateur botanists such as Petrie (1883, 1895), we have at the present time little directly recorded evidence that European man caused any early change in the natural grassland vegetation or in its cover of soil. I have summarised elsewhere (O'Connor, 1982), some very cogent botanical argument that there were substantial pastoral effects on the physiognomy of vegetation, depletion, reduction in the scrub component, reduction in grass stature and what was later defined as deterioration, "a reduction in palatability through the destruction of palatable species".

This definition, as enunciated by the Southern Pastoral Lands Commission (1920), doubtless reflects the mind of Leonard Cockayne, member of that Commission and at that time actively engaged in revegetation research. It seems ironic that Cockayne may have apparently grossly underestimated the degree of such pasture deterioration which had occurred by about 1880.

Pastoral influence on grassland

In his early account Buchanan (1868) had listed grasses under three headings: first quality, second quality, and alpine. Among the 12 species of first quality, five are described as "valuable small tussock grasses", including three Agrostis species and Poa australis, later recognised as Poa caespitosa. Among the 13 species listed as of second quality (of which two occur also in the first quality list), two Danthonia snowgrasses and two smaller Danthonias are included. In the third class which he termed "Alpines, found from 4000 to 8000 feet" (sic!) 12 grass species are found, including the only fescue (Festuca duriuscula) and what he then termed Triticum scabrum (now principally Elymus rectisetus) together with five Poas including P. colensoi and P. anceps. Some caution needs to be applied in interpreting the third group "Alpine". It is likely that several of these species, including F. duriuscula and T. scabrum were to be found below

4000 feet. Clearly, however, they are to be contrasted with the lowland and induced element which clearly included Poa australis var. laevis. In his "Manual of New Zealand grasses", Buchanan (1880) described some 85 species or varieties which were considered indigenous. Of these some 60 were found in South Island grasslands, apart from those confined to coastal or insular habitats. Six of these were snow grasses or other large tussocks. Thirty-five of the the remaining native grasses including several Agrostis species, small Danthonias, Trisetum species and several Poa varieties were assessed as having pastoral value. Of these 35, ten including D. semi-annularis, Agrostis avenoides and Hierochloe redolens were indicated to have been adversely affected by overstocking or burning in the previous 15 years. Several of the others, including the small and intermediate size Poa tussock species, were identified as having recuperative abilities. Many of the smaller Poas were considered of minor importance or limited extent except in alpine conditions. One of the Poa varieties (Poa anceps var. b., foliosa) was described not only as "the most abundant and widespread grass in New Zealand", found from sea level to 5000 feet altitude, but also "as one of the most valuable in New Zealand for although a few others may prove more nutritious, it resists better the exterminating effects of both drought and fire, thus ensuing a certain amount of permanent pasture". A noteworthy feature is that the taxa which emerged as the principal "short tussocks", Poa australis var. laevis and Festuca duriuscula, are noted as being variable and the first also of variable value as livestock food.

A parallel situation can be pieced together in Canterbury. Wilkin et al. (1872) reported on their attempts as a Committee of the Canterbury Philosophical Institute to compile from questionnaires to interested persons information on distribution, habitat, phenology, resistance to frost and drought, acceptability to livestock and nutritional value of 33 indigenous grasses of Canterbury. They failed, through widespread unfamiliarity with botanical names and lack of any differentiating common names in English or Maori language, a situation not greatly changed more than a century later. Armstrong and Armstrong (1872) compiled an appendix list of 42 grass species indigenous to the Province of Canterbury. Of this species list approximately 35 were not confined to specialised coastal habitats. At that time Agrostis aemula, A. pilosa, A. canina and A. avenoides were abundantly distributed on the alps and plains and were counted as valuable cattle and sheep grasses. Agrostis parviflora and A. quadriseta were common on the alps and some parts of the plains but were counted as of little value. Dichelachne crinita was considered a valuable and abundant grass, Koeleria cristata as common on the plains and Malvern Hills and "one of our best pasture grasses" while Danthonia semi-annularis, although common throughout the province, was "so closely cropped by cattle and horses that we had considerable difficulty in obtaining specimens". Poa foliosa and Poa australis var laevis were described as common in the alps and low hills, both tufted and "very good pasture grasses". Poa anceps was identified as "the common tussock-grass of the plains and Port Hills". Poa colensoi and P. Lindsayi were alpine pasture grasses of considerable merit for sheep feeding. Festuca duriuscula (the only fescue listed), "the hard fescue, a small and valuable grass found all over the world in alpine pastures". Triticum scabrum was identified as "the blue-grass of settlers, a valuable grass found in many countries; in Canterbury it grows at an elevation of five to six thousand feet, and is certainly one of the best native grasses".

When J.B. Armstrong (1880) composed his sketch of the flora of Canterbury he divided the Province into four districts, the Littoral, the Banks' Peninsula, the Lowland or Middle, and

the Alpine districts. He lamented the injury to the well-grassed northern slopes of the Peninsula ranges "by the senseless system of burning, which I am sorry to say, still prevails in the district". Of the Lowlands or Middle District which embraced the plains and downs and the eastern foothills of the alps up to 2000 feet, he wrote:

> "The most abundant grasses are the tussock-grass Poa caespitosa etc., an undescribed species of fescue usually referred to Festuca duriuscula by most New Zealand collectors. The tussock grass Aira caespitosa, Agrostis aemula; the holy grass, Hierochloe redolens; the plume grass, Dichelachne crinita; and the blue-grass, Triticum squarrosum".

Grasses which he tabulated as abundant in the alpine district were: Hierochloe redolens, Echinopogon ovatus, Dichelachne crinita, Agrostis canina, A. parviflora, A. aemula, A. pilosa, A. avenoides, A. quadriseta, Arundo conspicua, Danthonia cunninghamii, D. raoulii, D. semi-annularis, D. pauciflora, Aira caespitosa, Koeleria cristata, (which he now considered naturalised), Trisetum antarcticum, Poa foliosa, Poa anceps, P. caespitosa, P. colensoi, P. lindsayi and Triticum squarrosum.

In considering the forage plants of Canterbury, he asserted that the most nutritive grasses he had so far been able to ascertain were "the various species of Danthonia, Microlaena avenacea and Poa foliosa; but these are not however, the best adapted for cultivation, owing to their general coarseness of habit and liability to die out". He listed as best native grasses "for general farm purposes, fully deserving a trial from all farmers anxious to improve the productiveness of their pastures", the following: Microlaena stipoides, Dichelachne crinita, Agrostis canina, Agrostis youngii, Danthonia semi-annularis, Triticum squarrosum, Poa breviglumis, P. foliosa, P. intermedia, Trisetum antarcticum and Hierochloe alpina. He also suggested "the aromatic aniseed Angelica gingidium of which sheep are so fond that they have exterminated it in many parts of the province", as well as Ligustium haastii and others of the genus. Of the recommended grass species he wrote: "Since the introduction of sheep and cattle these native grasses have considerably improved in productiveness, except where the senseless burning system has been carried to excess".

It is not always easy from these accounts to discern when there is a change of plant abundance and where there is a change in plant nomenclature. Discounting such difficulties, some apparently important trends up to 1880 emerge. First, at lower altitudes in what are at present considered to be lowland and montane zones, recovering scrub and forests gave way to grasslands in which poa rather than fescue species were more prominent. Second, tall tussock grasslands were reduced, especially in the lowland and montane zones under the influence of fire and livestock grazing. Third, the selective pressure of livestock grazing in all zones resulted in reduction of more favoured elements. The corollary of this last is most important, for it indicates that such grasslands deteriorated in quality, and that this deterioration may have occurred by preferential grazing within variable species as well as between species. Grasslands of characteristic tussock physiognomy could have been derived from such differential grazing, where the less acceptable plants were allowed to flourish as tussocks rather than merely as tufts.

This may well have been the period of the creation of short tussock grasslands, especially the fescue tussock grasslands with which we are now familiar. Connor (1961, 1964) and Connor and Macrae (1969) have traced the formation of short tussock grasslands in Canterbury and North Otago by a history of fire and grazing, from what were often tall tussock grasslands, formerly dominated by one or other of the species of Chionochloa or snowgrasses. No doubt a similar

process occurred on some terrain in Otago described in early European times by Buchanan (1868) and a century later by Mark (1965). What is here suggested is that short tussock grasslands may also have been induced by differential grazing pressure to promote tussocky physiognomy. Tussock emergence may also have been assisted by invasion of short grasslands and subsequent increase of less palatable forms of silver tussock and hard tussock. The evidence for such changes should be examined.

Emergence of tussock physiognomy

Reporting on his 1857 survey of southern districts of Otago (including Southland) Thomson (1859a) wrote:

> "The subject of Pasturage appears to me to be as important as any to this part of the Province of Otago. The natural grasses are always found to grow in bunches known by the name of tussocks, and these tussocks vary in colour and dimensions with the qualities of the soil and the nature of climate. In the lower and moister districts near the sea, the tussocks are sombre coloured, varying from red to brown, and attain considerable dimensions, rising above the ground at times to the height of four and even five feet. In the higher and drier districts the tussocks are light coloured and small, affording fine and soft pasture".

It seems evident from this that such "fine and soft pasture" was not constituted of what we now know as red tussock. Neither does it appear from the report as a whole to be what Thomson described as prevailing from 2000 to 5000 feet in the mountains north of the Waimea plains as "a coarse valueless tussock, locally called snow grass". Likewise in his report of his survey in 1857-58 of northern portions of the province, Thomson (1859b) indicates that mountain pasturage, being "composed of coarse tussocks or snow grasses" was generally inferior to that of the intermountain basins and valleys. Of the Upper Waitaki Plains he noted that they

> "lie on a higher elevation than the other districts described, and the grasses are generally scanty; yet owing to the dry, light, nature of the soils, these plains are well fitted for rearing stock".

Garvie (1859) in his report of his surveys in 1857 and 1858 into parts of the Taieri, Clutha and Mataura catchments notes that away from the coast, "pasture generally becomes very coarse when the elevation reaches 2000 feet" with snow grass mixed with cotton plants on the spurs and mosses appearing in gullies. He also noted the tolerably good pasture on the Raggedy ranges up to nearly 3000 feet altitude, which he imputed to a drier climate, and on the summit of Rough Ridge at 2800 feet noted that snow grass was "about equally mixed with a fine soft green grass - a kind of poa, which appears to be peculiar to this locality". In the Manuherikia Valley, he noted the very fine pasture "on the south side, near its mouth" but reported that "on the opposite side, and also further to the east the grass becomes rather thin and consists almost entirely of one species - a kind of oat grass, with a black seed".

Of this same Manuherikia terrain Buchanan (1868) wrote: "Over this large district, the country is open grass, and when first visited, of a remarkably sparse growth, consisting of three species on the terraces but richer in the small valleys. A little scrub was at that time, found on the banks of the Manuherikia, chiefly Olearia virgata".

Buchanan had come to Otago in 1849 and had been sending interesting plants to Sir Joseph Hooker at Kew for some time (Glenn, 1950). It was his botanical knowledge on which James Hector (1868) relied in outlining the geographical botany of New Zealand by zonation of Otago, altitudinally and from west to east. In his outline Hector sketched the drier interior (Zone C_1) as characterised by arid flora, oat and barley grass, toumatoukuri and rigid

speargrass. The moister eastward Zone C_2 he sketched as having yellow tussac grass, flax, tutu, fern and soft speargrass. Between them in Zone D_2 where the open country of the eastern plains rises above an altitude of 3000 feet, there also, snow grass, Veronicas, Celmisias and other plants characteristic of this (subalpine) zone, "displace the more nutritious pasturage of the lower grounds". In this respect it resembled the subalpine zone immediately to the west of the dry interior where it extended from 3500 to 6000 feet, "especially distinguished by the prevalence of large bunches of Snow grass, which term includes various species of Danthonia and Agrostis, intermixed with scrubby patches of Dracophyllum and other heaths, many beautiful Veronicas, and a great variety of composite plants, principally Celmisias, Senecios and Cassinias". Zone E, the alpine region, which he represented only on the Main Divide, was characterised by patch plants where "all the flowering plants that form wood are nearly stemless, and in most cases are aggregated in the form of hard hassock-like patches".

These summary features of the Otago geographic botany were presented by Hector (1868) to illustrate "the chief physical peculiarities which regulate the distribution of the vegetation in the South Island". The only characteristic "tussac" other than snow grass named in it is the "yellow tussac", later to be interpreted as Poa caespitosa, in the same general zone as that described by Buchanan (1868) from his earlier visits, as recently forested terrain.

What is noteworthy is that nowhere in these writings, or in his own early essay on the botany of Otago (Buchanan, 1868) or in his manual of the grasses of New Zealand (Buchanan, 1880) did Buchanan describe a fescue-dominated grassland or even a short-tussock dominated grassland. In his manual of the indigenous grasses of New Zealand, Buchanan (1880) writes of hard fescue grass, Festuca duriuscula L. as referred to in the Hooker's Flora of New Zealand, describing it as a "tall, slender, densely tufted grass", not as a "tussac grass". However, he uses that term 'tussac' for "tussac poa", now Poa caespitosa, for Poa colensoi, and for the "oat tussac grasses" now Chionochloa species. Buchanan describes hard fescue grass as "a very valuable grass, occupying a prominent place in all mountain pastures, being productive in every variety of soil and possessing a great capacity of adaptation to both aridity and moisture. It is subject everywhere to much variation and several of the varieties are known by other names". He also recognised that subalpine forms sometimes resembled Festuca ovina but considered it very improbable that such varieties had been introduced.

Some years later, Petrie (1895) reviewing his 20 years of botanical explorations in Otago and Southland referred to hard fescue in these terms:

> "Festuca duriuscula L. Most abundant at 1000 ft and upwards, both on the dry plains and on the hills and mountains of the interior.....This species has been confounded by some botanical workers and most settlers with Poa caespitosa Forst. It is a much more valuable grass than the latter which is eaten only when very young. Together with Agropyron scabrum (now principally Elymus rectisetus) and Poa colensoi, it forms the main sustenance of the great flocks of sheep depastured on the uplands of the South Island".

As will be demonstrated in what follows, the myth of short or low tussock grasslands did not clearly emerge until the second decade of the twentieth century. Indeed the term "tussock grassland" was not used until that decade. The evident feature of reality shown in so many of the early photographs which marks the end of the pastoral establishment period is of discrete tussocks, often reduced to butts. Is it not possible that the discrete tussock form is an artifact of pastoral use, indeed in those members

of a vegetation which were less preferred by livestock and so favoured in competition? This issue requires sustained and shrewdly designed experiment for its solution. The difficulties arising from uncertain taxonomy of many grasses, including both fescue and poa tussocks, were to persist for many decades. What was not for many decades conceived was that these species had much less importance as tussock in the pre-European landscape.

Early science in retrospect

So much is argument from hindsight. There has been no scientific finding as such from early science for it confined itself to resource survey, collection, observation and commentary, not to rigorous testing of explanatory conjectures. Such early activity as has been recorded of survey and observation served more to confirm the contemporarily founded pastoral myths than to doubt them. For example, early naturalists' commentaries such as that of Buchanan (1868), written in the early 1860s as the fruit of major expeditions into the interior of Otago from 1852 to 1862, are as much concerned with the qualities of pasturage as they are with other aspects of botany. Surveyors' reports like those of Thomson (1859a,b), Garvie (1859) and McKerrow (1862) and lay commentaries and accounts from the period such as those of Weld (1851), Butler (1863; and in Maling, 1960), Kennaway (1874), Roberts (1895) and Barker (1873, 1883) are concerned much more with assessing and adapting the new environment and vegetation for sheep raising than with any adverse effects of then current pastoralism on the condition of resources. Kennaway (1874) and Burdon (1938) record the concern in the early, tentative days of Canterbury pastoralism for the safety of sheep from winter snow. McKerrow in his 1862 report to Chief Surveyor Thomson reveals the same concern with safety from snow in assessing Otago country for pastoralism.

The "wastelands", as the grasslands of the interior were officially entitled, were appraised by pastoralist, surveyor and naturalist assistant alike as land suited or capable of being made suitable for livestock raising. Apart from the warnings of Garvie's report and the oft-cited caveat of Buchanan against "the repeated burning of the pasture in arid districts which is so frequently practised", there is little evidence of any concern before 1880 for the condition of the tussock grasslands. Buchanan was accompanied in print by writers from other districts (Monro, 1868; Travers, 1868) as well as Hector (1868) without being matched with like warnings of grassland deterioration in Canterbury or northern districts, although, as noted above, Armstrong (1880) was to join him later in complaining about senseless burning. Despite its infrequent character and despite the likelihood that this caveat was based on surmises and observation rather then controlled experiment, let us not underestimate Buchanan's warning. He noted (Buchanan, 1868): "Much of the grassland of Otago has been thus deteriorated since its occupation, by fire, and it is no wonder that many of the runs require eight acres to feed a sheep according to the official estimate". Two features are especially important concerning this observation and commentary. The first is that it is early in the eruptive phase of pastoralism written by 1865. The second is that careful examination of this text indicates that the deterioration complained of is destruction of finer grasses, not reduction of the tussocks themselves. In essence it is a pastoral concern.

Seen in the whole context of the two or three decades of a colonial economy in which pastoralism was being established, the recorded comments of the few scientists who visited the tussock grasslands do not constitute a judgment upon pastoralism. Scientists were not in those days, professionally trained in either the logic of discovery or the techniques of biological experimentation. Some of them such as

Hector, Monro and Sinclair had professional training in medicine which was an accepted pathway to natural science (Glenn, 1950). For the likes of Buchanan who had to win his spurs by thorough field and bench performance, it was neither prudent nor easy to pass judgment on what was the accepted mode of land use of the establishment phase. Nor indeed do they make general judgment upon burning as a tool of pastoralism. "Scientific disquiet" is perhaps a more appropriate term. Much more concern was directed at the expansion of grazing land by the burning of forests and flaxlands (Travers, 1871; Wynn, 1979) and at the emergence of the rabbit pest (Petrie, 1883). We can conclude that science story-telling, such as it was in the first phase of pastoralism, was essentially the same in message as the current utility story-telling. As story-telling, Buchanan's work is a remarkable achievement. We have great difficulty at this distance in determining whether he was able to subject his stories of early abundance of palatable grasses and their destruction, to the rigorous testing which makes genuine science.

Ineffectiveness of science

In the light of the comments made above on the relative powerlessness and lack of prestige of the botanical scientists who were doing the work, it is not surprising that they had little effect in altering the direction or pace of a major land use. It should be noted that Buchanan (1868, 1880), Armstrong and Armstrong (1872) and Armstrong (1880) all made positive suggestions for the use of the indigenous grasses more suited to improvement of pasturage. Apart from such recommendations and their supplementation by evaluation and promotion of introduced grasses (Boys et al., 1872; Duncan, 1872; Mackay, 1887), agrostologists and others of scientific inclination had no solutions to offer to whatever constituted the grassland problem. As Dunbar and Hughes (1974) and Connor (1974) have pointed out, land abuse was not pursued as an end in itself but arose from limited understanding of indigenous conditions, perhaps guidance from the "bush burn" experience of Australia, and certainly from soon being trapped in an economic vice from which there was little escape (Gardner, 1981; O'Connor et al., 1986).

The vice was also ecologic. Butler (1863) and Lady Barker (1883) may have had vicarious satisfactions from a good day's burning. "Burn you must" was an initial imperative, as Butler (1863) recognised, for livestock settlement. "Burn you must continue" may have become more and more imperious the longer it was continued as a recurrent practice. If the effect of early pastoral use was, as conjectured here, the transformation of several series of seral grasslands and shrublands into increasingly tussocky grasslands where low acceptability to livestock was the consequence of an unconscious selection pressure, then frequent burning would become essential to promote palatability.

It is noteworthy that as early as 1880 Buchanan had a clear view of the shelter role of tall tussocks, and considered that they could be cultivated and used for such a role in the future. Of Danthonia raoulii, which was then interpreted to include red tussock and at least some of the narrow-leaved snow tussocks now included in Chionochloa rigida, Buchanan (1880) wrote:

> "This species forms the largest tussacs of the family and was very abundant in Otago and Southland before the occupation of the country by settlers. At that time the pasture was very superior, chiefly from the shelter afforded by the numerous large tussocks to the growth of the smaller grasses which were then abundant. Injudicious burning, however, had destroyed all these finer grasses before the enclosure of the land by fencing. On improving land intended exclusively for pastoral purposes, or for the raising of large stock in

districts exposed to cold winds it may be questioned whether the entire destruction of the native grasses, especially the larger tussac kinds is judicious, as their conservation, or culture, where they do not exist, would certainly prove an element of profit, not only for their own intrinsic value as food, but also, from their sheltering all kinds of stock as well as protecting from the nipping winds the smaller grasses which should form the bulk of every pasture. The indigenous grasses of New Zealand are undoubtedly more permanent and fattening than the introduced grasses of cultivation, and it might prove expedient in many districts, to adopt a mixed system, by which the larger tussac grasses, both native and introduced, might be planted out as shelter along with the main pasture composed of the most permanent species of which seed can be procured, whether exotic or indigenous, as not only would increased profit accrue by the adoption of such a system, but the painful spectacle be avoided of well-bred sheep with no other shelter from the cold than a wire fence".

It has been indicated in this account that scientific enquiry into agrostology and related pastoral matters was not the monopoly of a professional elite but was participated in by practical men and women. Why did they not take the practical advice of Buchanan cited above? I suspect it was a choice already blocked by financial constraints. For the lowlands the option of alternative husbandry with cash crops and of gorse hedge shelter was perhaps more attractive. For the highlands the traditional ideal of livestock shelter from tall tussock was nourished and has persisted to the present day. Yet high country runholders and their managers remained in a craft of "stockmanship" rather than "landmanship" (Dunbar and Hughes, 1974). Their tussock might grow so sparse as to be "non-burnable" under the continued grazing pressure of sheep grown to their maximum numbers on unimproved range plus the now increasing hordes of rabbits. So long as mortgages and rent could be paid from the shearing of perhaps hungry sheep, they continued to battle on.

Landmanship was not a conspicuous feature of the land administrators or legislators themselves. There is little doubt that by 1880, pastoralism was no longer an attractive investment. Wool prices had fallen in the 1870s, rabbit plagues were severe in most parts of the high country, alternative opportunities for the disposal of stock by a refrigerated meat trade were not yet open, and pastoral indebtedness was already high (Gardner, 1981; McDonald, 1952). Careful analyses of the major changes in pastoral land legislation and administration during this period (Jourdain, 1925; Blake et al., 1983) indicate that principal attention was given to secure the title and improve the conditions of tenure of the pastoral runholders at the same time as to ensure the proper payment of rent.

Scientists, of both nature and society, legislators, administrators and pastoralists should all pay attention to the great irony that this early and dramatic impact of pastoral use on New Zealand vegetation represents. In summary, the New Zealand colonial economy was founded as a dependent pastoral economy, even though official policy was to establish an agricultural economy. Pastoralism was rationalised as a transitory expedient but it achieved initial commercial security by exploiting the very laws and regulations set to block it. It was made legislatively secure by the time it was itself demonstrating its ecologic and economic instability (O'Connor et al., 1986). If a summary explanation is needed to account for the fact that successive administrations managed to achieve almost precisely the opposite of their intentions, I think it must be that they were reactive administrations, responding rather than planning, and responding belatedly to both ecologic and economic change.

The tragedy of the failure of science to influence the course of pastoral land use in this first establishment phase was later to be seen in a sustained separation of science and the administration of land use. The effect of this separation was shown in decades of failure to perceive or research the real problems of land use.

Science and pastoral deterioration

What is considered here as a "pastoral deterioration phase" is one which particularly characterised the industry of high country pastoralism. It is reflected in a general decline, often gradual at first, in the numbers of livestock carried on the high country runs. It is estimated to have begun after the eruptive period, or some two decades after the initial stocking of all the pastoral terrain of any district. As indicated by O'Connor and Kerr (1978) the initial stocking of high country runs was spread over nearly a decade and was begun approximately a decade after the initial stocking of the lowlands from livestock landings in the extreme north and south of South Island. Accordingly, the pastoral deterioration phase can be conveniently reckoned to have begun from the early 1880s. It is thus coincident with the general coverage of all counties for agricultural and pastoral statistics. The pastoral deterioration phase was to continue for some 70 years, although the decline in livestock numbers was not constant over time or uniform for all districts. As has been indicated for Canterbury high country runs (Walls, 1966; O'Connor, 1983) and for the unimproved range (mostly in pastoral runs) of Vincent and Lake counties in Otago (O'Connor, 1980) the most substantial aberration from a downward trend was the recovery of livestock load in the late 1920s and its remaining high during the years of the great economic depression before resuming its decline.

The first approach to this long period is to review the work of botanists, particularly Leonard Cockayne, in interpreting vegetation conditions and pastoral influence. We shall later see that this interpretation differs considerably from that discerned from the earlier observations and writings of Buchanan and Armstrong in particular. The second approach will be to identify the main lines of economic and pastoral enquiry led by A.H. Cockayne. The third section will be to review the stock-taking made by the 1920 Southern Pastoral Lands Commission. The fourth section will trace the beginnings and progress of agronomic research into revegetation especially for the depleted lands of Central Otago and the Upper Waitaki including the Mackenzie Country. The fifth section will summarise the syntheses of botanical, geographical and pedological scientists up to the end of this pastoral deterioration phase. The final will be to summarise the interactions of land administration and practical pastoral use with this desultory scientific activity.

Interpreting low-tussock grasslands

The degenerative phase of New Zealand pastoralism continued from the 1880s for another 70 years (O'Connor, 1980). It was not everywhere marked with such obvious changes in vegetation as Petrie (1883, 1895, 1912) revealed for Central Otago. Poppelwell (1912, 1913, 1914, 1916) reported on the vegetation of the western mountain ranges of Otago. Whereas in the drier mountains to the east Petrie (1912) remarked on the depletion of grassland to a semi-desert, Poppelwell (1914) noted on the Garvie Mountains that fescue (apparently now F. novae zelandiae) was common and Poa caespitosa abundant in the lower steppe (1000 to 2700 feet), above which Danthonia raoulii (now Chionochloa rigida) was plentiful. This suggests an upward and westward march of Poa caespitosa just as Petrie (1912) recorded the upward march of depletion. Petrie (1915) noted the rarity in Southern Otago of Deyeuxia youngii, once considered quite abundant by Buchanan. He also noted that Buchanan had at one time believed Poa anceps to be common in Otago and while on a botanical outing with Petrie, had expressed great surprise in not being able to find it. It may also be

observed that the Armstrongs (1872) have earlier in this essay been noted as identifying Poa anceps as "the common tussock-grass of the plains and Port Hills". Although from Petrie onwards there has been general acceptance among agrostologists that P. anceps is principally a North Island species, it is puzzling that an approximately similar confusion of Poa anceps with what became Poa caespitosa should have been made both by the Armstrongs and by Buchanan.

Leonard Cockayne followed his experimental horticulture at Christchurch from 1884 with extensive field observations culminating in field and controlled environment studies of subalpine and alpine plants (Cockayne, 1898, 1899). It was only a year later that "oecology" had its first formal and substantial field introduction to New Zealand in his sketch of the plant geography of the Waimakariri River basin (Cockayne, 1900); Cockayne began by expressing his mixed feelings at Diel's German publication in 1896 on the Vegetation Biology of New Zealand and then made his own apologia:

> "That a field botanist in a distant colony can endeavour to solve any of the very difficult problems which plant oecology presents is hardly to be expected. The very fact of being at active work in the field hinders the close study necessary before approaching and while engaged in such work; also, the almost entire lack of recent literature makes critical work quite out of the question. These higher problems - e.g., the verifying or disproving hypotheses by accurate physiological experiments; the collecting multitudes of facts from the records of many writers; considering such, and deducing conclusions therefrom; or the examining material collected from all over the world to establish some point - such work and the like can only be attempted by men of great natural ability, special knowledge, and vast learning, with the most modern appliances to hand, and access to the literature of any particular subject".

Cockayne's concession of his own limitations having been thus made, he then went on to assert the importance of field study at all seasons of the year and persuasively presented his own interpretative argument, using climatic, phenologic, and plant distribution data.

In 1910, in the first edition of "New Zealand Plants and their Story", Cockayne (1910) wrote of New Zealand grasslands as tussock meadows, acknowledging that they belonged to different biological categories that were by no means clearly defined e.g. steppe, fell-field etc. Cockayne recognised the tussock meadows of the montane regions and the lowland plains as of great commercial importance. He noted that the grasses were now in so many cases replaced "by those of Europe and by the host of introduced weeds". "The tussocks belong especially to two species Poa caespitosa and Festuca rubra (now F. novae zelandiae). As a food for stock the poa is not of much moment, but Festuca rubra is of considerable value". Other valuable grasses he identified as Poa colensoi, Agropyron scabrum (now Elymus rectisetus) and the various forms of Danthonia pilosa and D. semi-annularis "since they will tolerate burning and increase naturally upon the poorest ground". In discussing the "evolution of meadows" Cockayne traced the colonisation by plants of the characteristic broad shingly riverbeds and debris fans by Epilobium, Raoulia, lichens, mosses and drought-resistant shrubs, (Discaria, Cassinia, Carmichaelia), together with grass-tussocks. He also noted that where a hillside forest has been burnt and "there are frequent winds, trees cannot be reinstated and meadow will result. Such fires have been frequent even in the pre-European days". He speculated that, since the destruction of upland beech forest (Nothofagus cliffortioides) by fire may be so thorough as to destroy tree-seeds in litter, it was not impossible that such

treeless areas as Central Otago may have been "long ago occupied by more or less extensive forests".

He described the meadows of the high mountains at greater length, recognising their extent and floristic variation from the mountains near East Cape and over the high summits of both Islands to the hills forming the southern part of Stewart Island. He noted that "these high mountain meadows were by no means closely growing associations of plants. On the contrary, these latter are generally in clumps, or dotted about, the ground between being quite bare, and the amount of bareness is governed by the rainfall". He concluded: "Frequently the meadow is dotted with veronicas and other shrubs. Large breadths of an alpine Astelia are often present, also tall tussock-grasses such as Danthonia Raoulii and D. flavescens". Cockayne (1910) also described the peculiar series of plants which are now known as scree plants and interpreted this "shingle slip vegetation" in this way:

> "The rocks of the alpine summits weathering away, and the rain not being sufficient to bear all the debris into the valleys, an enormous quantity of angular stones collects on the mountain-sides in many places, which may form steep slopes for thousands of feet....All is a scene of utter desolation: it is, in truth, an alpine desert. Yet many of the meadows must have begun their career as shingle slips, and all transitions may be noted from the one to the other".

By the second edition of 1919, the tall tussock grasslands were put in clear perspective (Cockayne, 1919a). The first edition of "Vegetation of New Zealand", evidently composed before the first world war but not published until 1921 (Cockayne, 1921), used the term "steppe" for the grassland. However the term tussock grassland was brought into vogue by Cockayne and Foweraker (1915). Writing of low tussock grassland in the vicinity of Cass they wrote:

> " 'Tussock grassland' is here used as a substitute for the term 'tussock steppe' hitherto used by L. Cockayne in his ecological publications. The reasons for abandoning the word 'steppe' have already been given. All the same when attention is called to the effect of overstocking and burning in increasing the percentage of bare ground to that clothed by tussock etc until, as in Central Otago, desert pure and simple is established, there is certainly an induced steppe association in New Zealand just as there is induced desert. Such induced steppe, however, we would now term 'open low tussock grassland', a term having the merit of defining itself".

Cockayne (1919a) represented "the great tussock-grassland plant-community" as falling into "two distinct classes, according to the conditions the dominant tussocks and their companion plants can and cannot tolerate - the relative amount of light, of rain, and of the degree of 'sourness' of the soil being perhaps the determining factors". Accordingly he propounded "tall tussock-grassland" and "low tussock-grassland" as distinct plant-formations.

It is worth noting at this point that in the evolution of Cockayne's ideas as traced here in the words and phrases he used, there is a distinct affirmation of ecological principles from the outset, a clear recognition of the need to falsify or verify ecological hypotheses, especially by physiologic experiment, and a progressive modification of initial dominantly climatic hypotheses as his experience and information widened. Thus from his initial ecological sketch of the plant geography of the Waimakariri, which is dominantly climatic in interpretation, with principal emphasis on precipitation, he gives further attention to the interaction of climatic factors such as wind with the processes of primary and secondary succession. Likewise, he acknowledges the influence of new forces, such as burning and grazing, on the condition of

the grasslands, interpreting the low tussock grassland as a climatically-controlled plant formation which is modified by these forces, depleted to open low tussock grassland and ultimately to scabweed desert. At this point he does not appear to have made such a genetic connection between the tall tussock grassland and the low tussock grassland. In fact, the "tall tussock-grassland" seems to have had to struggle until 1919 to emerge as a concept in Cockayne's vocabulary, having previously been dominated by concepts such as alpine herb-field and fell-field.

Cockayne (1919a) credited what have become the Chionochloas as constituting tussock grasslands rather than seeing them as components of meadows or herb field. He carefully described the red tussock Danthonia Raoulii var. rubra and physiognomically outlined the red tussock grassland of the Southland Plain, without mentioning any grasses among the companion plants named. He noted the "most decided subalpine stamp" of this plant association extending from sea level to the limit of the montane belt, and also extending to Stewart Island. Of its use he wrote:

> "The tussock itself, under the name of 'snow-grass' is well known by shepherds for its worthless character as sheep-feed. Unfortunately they call at least two other plants by the same name".

He also noted that tall tussock grassland differing in composition from the above was more or less common in the high mountains. He outlined the red tussock grassland of the Volcanic Plateau of the North Island at 3000 to 4000 feet and the hassock-grass (Danthonia australis) association which occurred in northern parts of South Island.

Clearly Cockayne did not value tall tussock-grassland of any kind as of much economic significance at least for pastoralism.

> "It is low tussock-grassland which must specially be considered from the economic aspect; tall tussock-grassland of Danthonia Raoulii var. rubra is worthless, though the soil on which it grows may be rich enough when drained, as Southland can testify".

It appears from both this edition (Cockayne, 1919a) and from other writings of Cockayne that he considered that Danthonia Raoulii var. rubra included at least much of the narrow leaved snow-grass now ascribed to Chionochloa rigida. Even in the third edition of this work (Cockayne, 1927) he repeated the above-cited comments and descriptions, with one important modification. Whereas Cockayne (1919a) had outlined in brief the associates of the red tussock of the Volcanic Plateau botanical district, in the third edition (Cockayne, 1927) he simply noted that tall tussock grassland occupied considerable areas at an altitude of 3000 to 4000 feet, and proceeded:

> "Tall tussock-grassland of the high mountains more frequently has the broader-leaved Danthonia Raoulii var. flavescens (also called snow-grasses) dominant, especially on the wetter mountains. With it will be associated many of the subalpine herbs and low growing shrubs of the vicinity, but when in full vigour, as it cuts off much light, very little can be established. As a pasture plant, it is hardly eaten by sheep, and in winter, when it might be useful for shelter, heavy snow flattens it to the ground". (1927, p.128)

In contrast with this estimation (Cockayne, 1919a) had concluded his chapter on the grasslands:

> "In the subalpine belt especially of Central Otago, the Mackenzie country and part of Marlborough, the broad leaved snow-grass (Danthonia flavescens) is dominant in many places. This is probably the most palatable of all the tussocks. On the other hand, Danthonia australis is probably absolutely worthless. So, too, is the mountain

twitch (Triodia exigua) of the stony river valleys". (p.94)

It seems clear that Cockayne had changed his opinion at least of some of the tall tussocks. Broad-leaved and narrow-leaved varieties are, by 1927, both discounted as pasture plants. Cockayne (1919a) had extolled the durability of the natural grassland:

> "These for nearly seventy years have been occupied by millions of sheep; the tussocks have been repeatedly burned; rabbits exist on them in uncountable numbers; many foreign plants have secured a permanent footing and yet these tussock-grasslands, with but one exception, remain virtually unchanged. This speaks volumes as to the suitability of the tussock growth-form for its New Zealand environment. With a host of enemies arrayed against it, the tussock still stands supreme, except in the lowlands where it has fallen before the plough, or in Central Otago, with the dry climate and man arrayed against it". (p.85)

Alluding to this performance under sustained pastoral use for producing thousands of tons of wool, without any substantial improvement, Cockayne (1919a) wrote:

> "Certainly the number of sheep grazed per acre is very small, perhaps one to four acres being quite a liberal estimate. In the Mackenzie country more than thirty years continuous grazing has not lessened the carrying capacity of the whole area - in fact if the number of rabbits also grazing on the land be considered, its carrying capacity has increased. And yet over a good deal of that pasture-land the tussock has been wiped out". (p.93)

Seen in this context, the durability of the natural grasslands which Cockayne had extolled was of the low tussock grasslands. Cockayne (1927) omitted the last two sentences of the above quotation concerning the Mackenzie in the third edition. The question of interest is how and why did they come to be included in the second edition. Cockayne had journeyed to the Mt Cook region by the two-day coach trip from Fairlie in or before 1892 (Gillespie, 1958). I have no other record of his observations in the Mackenzie. The clues to his comments appears to lie in the published work of his son, A.H. Cockayne.

Economics of natural pastures

In 1904, Alfred Cockayne was appointed Assistant Government Biologist and in 1908 Government Biologist in the Department of Agriculture (Thomson, 1983). In 1910, he published the first paper of a short series "The Natural Pastures of New Zealand" (A.H. Cockayne, 1910) dealing with the effect of burning on tussock country. Under the slogan of Theodore Roosevelt: "the conservation of natural resources, and their proper use, constitute the fundamental problem of our national life", Alfred Cockayne addressed the problems as "proper conservation and utilisation to the best advantage" of the 15 million acres consisting "more or less of native grasses", being about 71 percent of "the 21 m acres under occupation in the Districts of Marlborough, Canterbury and Otago". He noted that for properties with country above 3000 feet "the grazing ground is more or less sharply divided into what is called 'summer country' and 'winter country'. The former can only be utilised during the summer months, being covered for the most part during the colder period of the year with a thick mantle of snow; while the latter is grazed during the greater part of the year".

Alfred Cockayne outlined the general practice of burning and grazing. For winter country burning is done as much as can be in spring "to destroy all the dead and harsh leaves of the tussock, and promote a rapid development of young and tender foliage which will be readily eaten by sheep". He also stated that "large portions of this country may again be burnt later in the

year" and noted midsummer and autumn firing as more or less unintentional. For summer country "the first burning generally takes place during the general muster for shearing". Signal fires by musterers were not extinguished according to Cockayne, and some runholders encouraged the practice "under the impression that such firing will have a beneficial effect on the pasture, and tend to improve its carrying capacity". During mustering to the ram in autumn and during the muster for wintering Cockayne claimed that further burning took place if the ground were sufficiently dry.

It is doubtful if Alfred Cockayne had any more than hearsay evidence for these statements of practice. Either he or his readers could have interpreted that the same terrain was burned more than once in a year, and at least annually. In reality it would be unlikely that such combustion was even widely possible, let alone desirable. In earliest days of settlement (Barker, 1883; Acland, 1980) and in more recent times, again when grazing pressure has not been high, (O'Connor and Powell, 1963), recovery from fire to a combustible condition was achieved in tall tussock at sites favourable to growth in about three years. Burning of the same terrain at more frequent intervals than three years would scarcely be possible in these middle years of admittedly high grazing pressure. So far as low tussock was concerned, where grazing pressure was much higher, burning was now virtually impossible on large areas.

Shorter grasslands such as had occurred at the beginning of pastoralism in drier parts of the Mackenzie and Central Otago, were apparently initially burnt for the reduction of scrubby plants and especially of speargrass (now Aciphylla aurea). We have the evidence and the warnings of such practice from the earlier surveying parties (e.g. Garvie, 1859; Thomson, 1859a,b; Buchanan, 1868) how tussock grasslands, now known to have been induced from tall tussock grasslands, whether Snow tussocks or red tussock, were also burnt for the reduction in scrub and speargrass, as well as to induce and maintain the shorter grassland more amenable to sheep use. By the early decades of the twentieth century, how frequently could such shorter grassland be burnt? Pinney (1981) reported that Omarama Station had from dry years and rabbits suffered a decline in sheep numbers from 45,000 in 1884 to 36,000 in 1903 and that Arthur Sutherland, the manager, "denied that burning also contributed, for there was not enough grass to light". Guthrie (1910), in his dissenting report as an "informal inspector" of Canterbury pastoral runs, offered as his opinion that the then mysterious grass grub was in particular areas making so much headway because "the tussocks on this barren country are so far apart that they are never able to be burnt in a general burning." Although Cumberland (1945) was to repeat the claim that "in the latter part of the last century annual burning was often the rule" (emphasis his), he acknowledged that burning became much less frequent in drier areas.

Regardless of the historical origins of the burning practice in making access possible and in reducing the volume of speargrass and scrub, there is widespread evidence from the earliest writers quoted earlier that burning improved the quality or productiveness of the pasturage, at least temporarily (c.f. Garvie, 1859; Armstrong, 1880; Acland, 1980; Butler, 1863, Barker, 1883, cit. supra). There seems little doubt then that pastoralists learned the expedient of burning tussocks themselves for the provision of more nutritious and palatable herbage. It has been my argument here (p.29 supra) that the promotion of increasingly tussocky grasslands by the unconscious selection pressure of the pastoral practices of settlement made more burning of tussocks virtually inevitable wherever it could be practised. By the combined depredations of past fires, continued but diminishing sheep and everlasting rabbits, the grasslands had suffered immensely. As the 1910

Commission on Classification of Canterbury Runs revealed, opinions were now divided about the wisdom of continued burning even though it was now virtually impossible over large areas. A.H. Cockayne (1910) found serious disadvantages for burning at any season of the year. He also recognised that the reason for its being practised was to promote regrowth of palatable herbage.

A.H. Cockayne argued from observation, from hearsay and from the interpretation of comparative sites differently treated in winter country. He acknowledged that legitimate burning could be appropriate when the effect and intention was to change the composition of the vegetation by eliminating undesirable elements of the vegetation, such as scrub, bracken fern or even rank silver tussock in damp soil. He rejected the more traditional justifications, the risk of widespread accidental fire, the threat of being overwhelmed by rank tussock, and the induction of short term palatable herbage in the tussocks themselves. He considered blue-grass (then Agropyron scabrum) as "the most important feeding constituent of the pasture, the young herbage that is formed after burning (being) greedily devoured by sheep, and in many cases the plants (being) eaten right out and killed". Nevertheless he saw the tussock grasses as

> "the most important element in these pastures as they not only provide the majority of the feed, but also act as a shelter for the finer grasses growing in an around them, which owe their presence entirely to the protection from wind and drought afforded by the tall-growing tufted habit of the tussock. Every care should be made to keep the tussock as intact as possible, as it must be looked upon as the sole agency which holds together the general plant covering... (p.9)"

In taking such a hard line against burning, A.H. Cockayne (1910) was joining a string of practical warnings subsequent to those of Garvie and Buchanan to 1880. Surveyor General McKerrow (1886), the Royal Commission on Land Settlement and Tenure (1905) and the Commission on Canterbury Pastoral Runs (1910) had successively warned against burning in different ways, the 1910 Commission going so far as to recommend that licences prohibit burning. Limited control over burning was provided by the 1913 Land Laws Amendment Act of the Massey Government and by 1922, full prohibition was provided, except with the consent of the Land Board (Blake et al., 1983).

A.H. Cockayne's condemnation of tussock country burning at all seasons and on all counts was addressed to winter country where the "main plants, so far as grazing is concerned" were listed: silver tussock (Poa caespitosa), hard tussock (Festuca rubra var.), blue-grass (Agropyron scabrum), blue tussock (Poa colensoi), red tussock (Danthonia flavescens) sic!, native oat grass (Danthonia semiannularis), plume grass (Dichelachne crinita). He acknowledged that burning had less effects in the summer country where it is "much more alpine in character but nevertheless the tussock form is often dominant, the red tussock occupying a more important position than in the winter country". He attributed this less serious situation to three general factors: summer country was not burnt to anything like the same extent; the land is spelled from grazing for a considerable period each year; rainfall is greater and vegetation has a better opportunity to reassert itself after all fires except late burns.

1910 is a year of some significance in New Zealand agricultural history. This paper of A.H. Cockayne was in the first volume of the new Journal of Agriculture. The same year is also taken to mark the "end of the twilight" for large estates (Gould, 1970). It also marks the first formal efforts by Government to promote revegetation of depleted winter country (McPherson, 1910). In 1911 following the Commission on Canterbury Pastoral

Runs, some run subdivisions were made, particularly in the Mackenzie country, even if these were to coalesce again within a decade or so (O'Connor, 1978). By 1915, A.H. Cockayne displayed a less unequivocal attitude to burning and was disposed to search more widely for the causes of lack of progress in the high country. In his contribution to Notes from the Canterbury College Mountain Biological Station (A.H. Cockayne, 1916) he writes:

> "To three district facts are attributed the lack of any progression in the utilization of upland tussock grassland:
> (1) the greater part of the land is held under a system of short leasehold;
> (2) our knowledge of what plants could be profitably substituted for the present vegetation is almost nil and the methods for the payable establishment of such plants are quite problematical;
> (3) individual runs are in general so large that they furnish ample incomes to their holders without the adoption of any special methods of soil utilization".

He notes that Festuca novae zelandiae is itself of little value but affords an indispensable shelter. He acknowledges the general opinion that "effect of stock has been to reduce very largely what runholders call 'the better and finer grasses', whatever may be meant by that very general phrase". He also notes that "replacement has been in the direction of an increase in dominance of the tussock growth form rather than in any reduction". He draws the conclusion that "it would thus appear then as if the tussock growth form is the only one that is capable of remaining permanently dominant over the montane tussock grasslands". He might with equally cogent logic have inferred that inter-tussock plants were generally more preferred as forage than tussock-forming plants.

A.H. Cockayne (1916) also investigated the question of pastoral deterioration or decline in carrying capacity. For four Waimakariri runs he totalled the sheep numbers for 1879, 1889, 1899, 1909 and 1914. These totals appeared relatively stable from 1889 to 1909 and the lower 1914 total was of the same order as the 1879 total.

From these data, Cockayne (1916) did not find conclusive evidence that there was a deterioration in carrying capacity. It may be noted that, as late established runs, these Waimakariri properties were below their full expected stocking load by 1879. In contrast to the Waimakariri situation, he noted 160,000 sheep fewer in Vincent County from 1879 to 1914, a decline to 330,000 sheep from a starting level of 490,000. He attributed the difference between the Waimakariri runs and Vincent County to the fact of no rabbits and a satisfactory rainfall in the Waimakariri.

He also examined changes in sheep numbers in Mackenzie County from 1884 (422,000) to 1893 (442,000), down to 394,000 in 1899 following the great snow of 1895, and then climbing to 495,000 by 1914. Cockayne wrote: "Here again it is seen that thirty years continuous grazing has not lessened the carrying capacity of the whole area". Yet he notes that there was a very large extent of country in this sheep district where the majority of the tussocks had died out so that part of it was virtual desert, yet there were 70,000 more sheep. A.H. Cockayne did not attempt to explain this apparent anomalously good sheep performance of the Mackenzie County, with both an abundance of rabbits and large sectors of low rainfall, the factors to which the comparative failure of Vincent County had been attributed! Connor (1964), Vance (1965) and Walls (1966) were later to demonstrate the true situation from access to Mackenzie country run records, rather than from the statistics of Mackenzie County as a whole. A.H. Cockayne might have found explanation for Mackenzie County's performance, not in the resilience of the montane tussock country but in the value of sown

pastures in the lower and moister country to the east of Burkes Pass and Mackenzie Pass. The quotation above concerning "30 years continuous grazing" leads neatly and directly to the illustration (Cockayne, 1919a) of the resilience of low tussock-grassland by reference to the Mackenzie country.

Re-assessment of the 1920 Commission

Leonard Cockayne must have heard arguments for and against A.H. Cockayne's view in the course of his participation in the Southern Pastoral Lands Commission of 1920. This commission (Commission on Southern Pastoral Lands, 1920) maintained the expression of strong belief in the high suitability of tussock form, reflecting the views of Leonard Cockayne as well:

> "The main constituents of the sheep-pasture are a number of indigenous grasses having one important character in common, the tussock form. Evidently this particular form of growth as it originally was dominant over all the South Island east or north of the forested area, is highly suited to its environment. This statement is strongly supported by the fact that, even after the pastures have been grazed without intermission for about seventy years, the tussock except in certain localities dealt with farther on still dominates in the pastures". (p.13)

Likewise it maintained the canard that

> "the sheep farmer early found out that none of the tussocks except the blue-grass (Agropyron scabrum) were palatable, but that if burned they, in their young leaves, would provide abundance of palatable feed. Consequently, throughout the grasslands year by year the tussocks were set ablaze, and year by year they were exposed to an increasing multitude of sheep".

The Commission generally found the maximum of depletion with the driest climate and reduction in depletion with progressively increasing rainfall, even though such non-depleted grasslands might still suffer from deterioration i.e. the replacement of more palatable species by less palatable whether indigenous increasers or exotic invaders. The poor opinion of the original vegetation is indicated by the remark concerning the changes in the grassland induced by burning and stocking:

> "On the credit side was the incoming of foreign grasses and herbs of higher palatability than any members of the original pastures". (emphasis mine)

The 1920 Commission has been fairly generally applauded for its interpretation of depletion and its causes as well as for its understanding of the prudence and practicalities of burning and not burning. Indeed the Royal Commission into the Sheep Farming Industry (1949) could do little more than endorse its recommendations concerning burning of tussock, recognise that on all Crown lands the consent of the Commissioner should be required and recommend that the Lands Department should see that each landowner (sic) has a copy of the recommendations of the 1920 Commission on the burning of tussock, and that landowners are encouraged to carry out these recommendations. The 1920 Commission advised on the circumstances under which burning should take place: (1) when the tussock has become more or less choked out by its dead leaves and stems; (2) only in the early spring when the ground is damp; (3) burn snowgrass (Danthonia flavescens) with caution and this rather for sheep access, not food. The same Commission identified the circumstances under which burning should not take place: (1) on sunny faces in an extremely dry climate; (2) where the tussocks are greatly reduced in size; (3) where it is likely to bring in an excess of unpalatable plants; (4) on greywacke mountains in vicinity of screes or on shallow soils liable to slipping; (5) in a dry climate where rabbits are numerous; (6) in the neighbourhood of rabbit-warrens; (7) near the sources of shingly rivers.

Such recommendations may have been prudent and reflect the considered wisdom of the time. No more than A.H. Cockayne's condemnations of a decade earlier can they be considered the fruit of science. In the preceding paragraph to these recommendations, the 1920 Commission identified that

> "not sufficient is yet known regarding burning per se. Experiments are urgently demanded so as to really learn what burning does with regard to the tussock itself and its accompanying plants. For instance, the following questions await an answer: How frequently can one and the same tussock be burnt? What amount of feed is produced after burning? To what extent and in what proportion do palatable and unpalatable plants come into new ground? Other questions suggest themselves, but the foregoing will suffice. Above all, adjacent sheep stations where burning and non-burning is carried out require comparison, as also those on which different degrees of burning take place". (C.15 p.21)

If there is any lesson to be learned about story-telling in tussock grasslands, whether of science or of utility, it must surely be that an unexpected audience is an occasion for impromptu stories. Commissions in 1905, 1910, 1920, 1940 and 1949 struggled with issues about tenure, rentals, condition of pasturage and the like, with little or no evidence that there was any systematic information service for such Commissions concerning sheep numbers, livestock output, grassland condition or the like. The Southern Pastoral Lands Commission (1920) acknowledged the difference between "depletion" and "deterioration" and the significance of deterioration as a reduction in palatability. It asserted of the evidence:

> "That such deterioration is greatly in evidence in all the land districts visited by your Commission is not only proved by the evidence, but from our personal experience and observations. Further the sheep returns distinctly show that a more or less gradual deterioration of the grassland has been in progress for many years. But these returns need not receive much attention, since in order to attain to accuracy a full history of each run is necessary and details of this kind are impossible to procure. We will cite only the extreme case of Vincent County, with its 511,188 sheep in the year 1880 and its 315,757 sheep in 1919".

The "extreme case of Vincent County" is unfortunately a record as much of "depletion" as it is of "deterioration", if we follow the distinction favoured by Cockayne and the 1920 Commission. It seems puzzling that the Commission should point to the evidence of "more or less gradual deterioration of the grassland" that was shown in the sheep returns, and then turn aside from presenting or making use of them. It is worthwhile therefore to look at the comparative records of sheep numbers and in area of sown pastures per thousand sheep for a series of counties or aggregates of counties. Six counties have been selected for which nearly 100 years of records can be assembled from the annual Agricultural and Pastoral Statistics, making adjustments for the boundary changes which have occurred, especially by fusion of Levels and Geraldine to form Strathallan County. The six include three counties, Maniototo, Waitaki and Mackenzie, climatically not greatly different from Vincent County, and two strongly differing from it. These are set out in Figure 3.

All counties illustrate substantial development of sown pastures, a partial replacement for the natural grasslands on which their pastoral enterprises were first based. Whereas this development was relatively late beginning and gradual in Maniototo and its neighbouring Vincent County, it was early and comparatively rapid in Waitaki, principally because of farming development in the coastal sector. Waitaki already had in the early 1880s as large an area of sown pastures as it

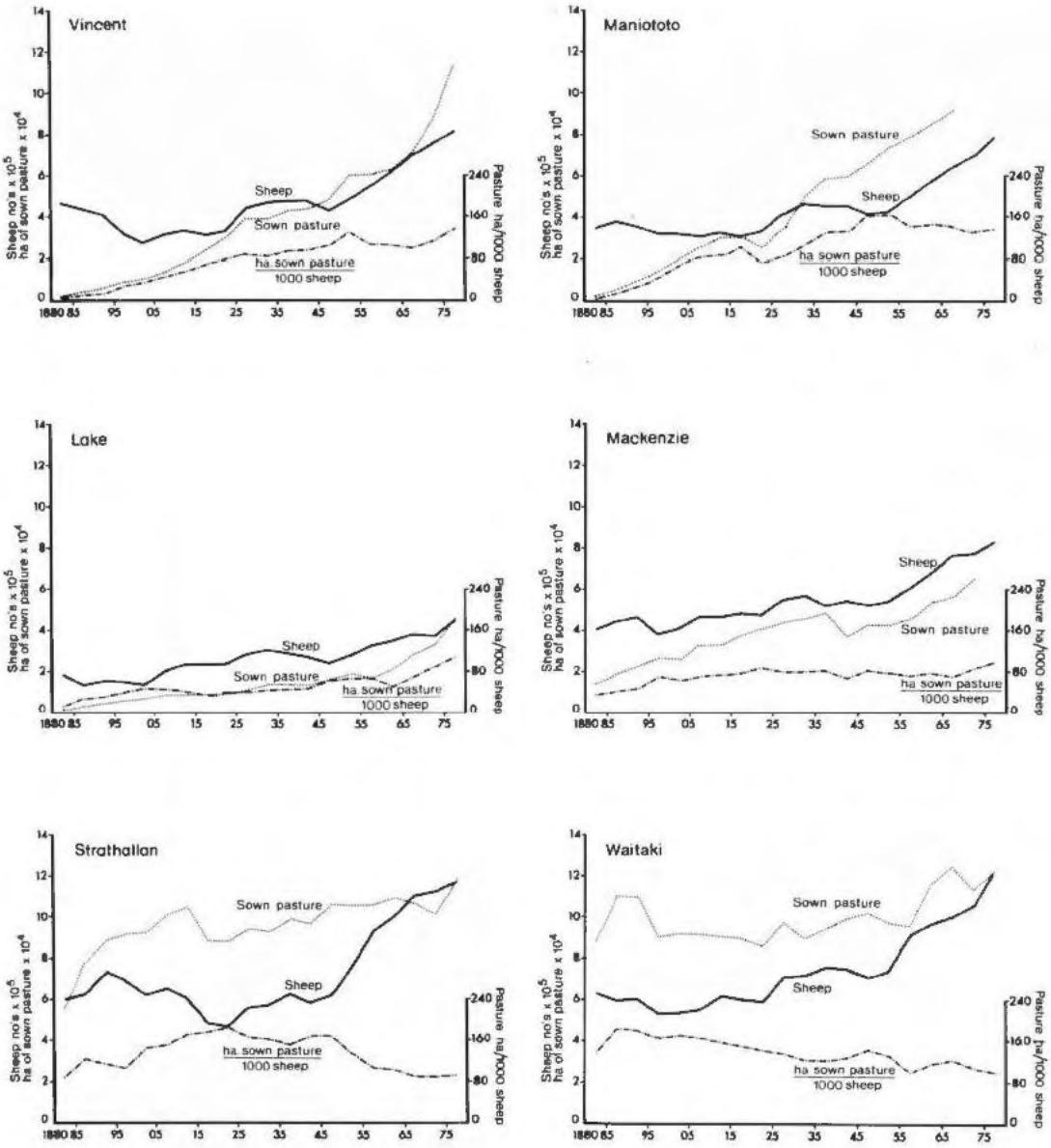

FIGURE 3: Mean sheep numbers and area of sown pastures per thousand sheep in selected counties of the South Island, New Zealand, for five-year periods from 1880-81.

was to have until the 1960s. It can be fairly clearly recognised that the pastoral replacement phase was already well advanced by the early 1920s when the ratio of sown pasture area per 1000 sheep for the eastern South Island reached its highest level (Fig. 2). The subsequent decline in area of sown pasture per 1000 sheep represents an increase in carrying capacity with pasture improvement. While this phenomenon is evident for the eastern South Island as a whole, it is not an obvious trend in counties such as Mackenzie and Maniototo where natural pasture replacement by sown pastures appears to have remained an influential feature even up to the present day. Sheep numbers by 1920 were lower in Maniototo and Vincent than they had been 40 years earlier. In Mackenzie and Lake they were higher, in Waitaki they were much the same. In Lake County they had declined sharply in the nineteenth century but recovered in the twentieth. In Strathallan they had declined sharply during World War I and were slow to recover. It seems that general sheep decline to the 1920s was not peculiar to counties which were predominantly semi-arid or sub-humid. Perhaps the only feature common to all counties was a surge in sheep numbers in the late 1920s and early 1930s, a feature earlier attributed (O'Connor 1976, 1980, 1983) to the pressures of economic depression. In contrast to the varied changes for total sheep numbers, the calculated load on unimproved range (Fig. 4) appears to have declined over a wider range of tussock grassland terrains.

The calculation of livestock load on unimproved range requires some explanation. Sheep returns collated by Walls (1966) for all Canterbury high country runs from 1900 to 1952 have been used to demonstrate graphically the decline during the first half of this century in sheep numbers for the Mackenzie country (O'Connor, 1976) and for Canterbury high country as a whole (O'Connor, 1983). As it is evident from many sources that sheep numbers may have begun to decline earlier than the turn of the century, an attempt has been made to estimate from the County Statistics the changes in stocking load on the unimproved grasslands. An attempt was made (O'Connor, 1980) to calculate such livestock load on the unimproved range of Vincent and Lake Counties combined, by totalling the area developed for livestock feeding, in both sown pastures and feed crops, and by allowing 10 sheep equivalents for each such hectare. These sheep equivalents were deducted from the total calculated as (horses x four) plus (cattle x four) plus sheep. The remainder was inferred to be the load on unimproved range. As there was no substantial change over the period 1880 to 1950 in the used area of unimproved range, the decline in calculated sheep equivalents on unimproved land was inferred to be a relative decline over time in livestock load.

Choosing a particular value for the "allowance per hectare improved for livestock feeding" would not necessarily invalidate any inference concerning decline in livestock load on a constant area of unimproved range. It could, however, materially affect the apparent gradient of any such decline. It could also invalidate comparisons in trends between different counties with different proportions of unimproved range. For the purpose of the present review, it was recognised that a value of 10 sheep equivalents per hectare was an excessive allowance. It was estimated that a more realistic allowance should be much lower and should be progressively adjusted over time, in line with the progress made in agronomy of sown pastures and forage and fodder crops. It was decided that the mean value of the allowance for all counties should be five sheep equivalents. It was also decided that it should be progressively adjusted each quinquennium from three s.e. per hectare prior to 1880 to five s.e. by 1930 and to seven s.e. after 1980.

Accordingly, Figure 4 partitions the total livestock as sheep equivalents in each of several counties into those

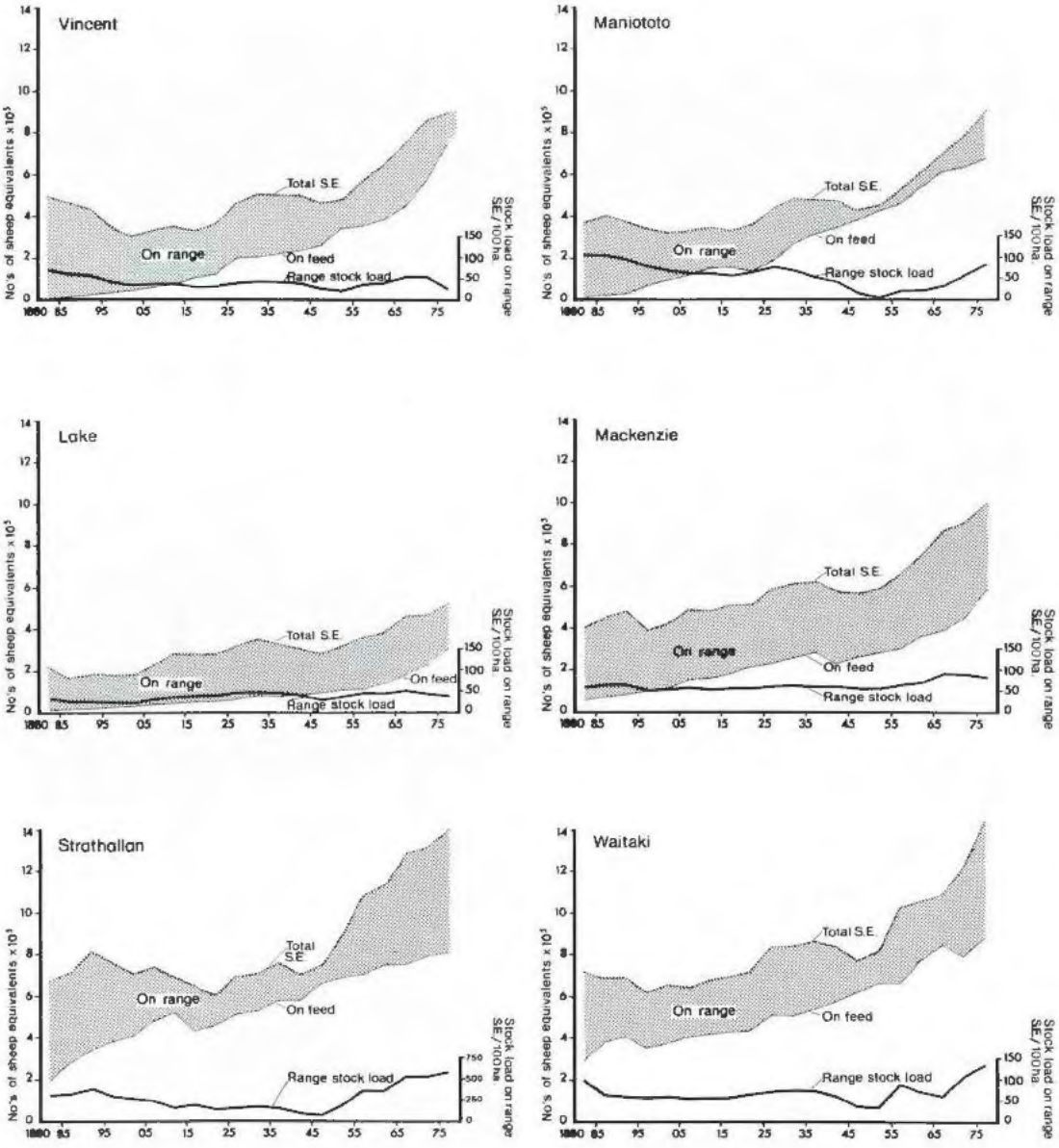

FIGURE 4: Five-yearly averages of total sheep equivalents and estimated proportion carried on improved pastures and crops for selected counties, South Island, New Zealand, 1880-1980. Calculated stocking load on tussock range is also shown as sheep equivalents per 100 hectares. Note that for Strathallan County the scale for stocking load is different from that for other counties. Note also that after 1955 all Counties show increased stock on tussock range as agronomic improvements are effected.

estimated to have been carried on improved land and the remainder inferred to have been carried on unimproved range. For each county, livestock load is calculated as sheep equivalents per 1000 hectares of unimproved range with adjustment for changes in area included in quinquennial estimates.

It is acknowledged that these estimates of livestock load are open to doubt. In fact they constitute nothing more than a set of hypotheses which can be tested by reference to the pastoral histories of individual counties or sectors of the high country. Where such testing has been done (e.g. O'Connor 1976, 1983) even over the limited period of 1900-1952, the characteristic overall decline in livestock load has been demonstrated on high country runs just as is indicated for unimproved range in these county calculations. These figures represent graphically the decline to the early 1950s of the traditional pastoralist industry.

The deterioration of pasture which had accompanied this deterioration in the traditional pastoral industry is also enigmatically indicated in Cockayne's (1919b) first report on his studies of relative palatability for sheep of various pasture plants. Many of the intertussock grasses previously assessed by Buchanan or the Armstrongs had not appeared on Cockayne's field assessment by 1919. Of those intertussock or low-tussock indigenous grasses assessed by Cockayne at that time to be at the lowest palatability level, Deyeuxia avenoides, Dichelachne crinita, Koeleria novo-zelandica, Poa caespitosa, Poa Lindsayi, Festuca novae-zelandiae and Agropyron scabrum were all nearly always assessed as of much greater relative palatability by the pre-1880 appraisals. It should be noted that "relative palatability" for Cockayne was assessed when sheep had a choice of these plants among others, including adventives. It might be inferred that adventive plants preferred to these native grasses represented a compensation for loss of more palatable elements as suggested by the 1920 Commission. It might equally well be inferred that Cockayne was observing the less palatable members of species from which the more palatable members had already been depleted by selective grazing. It is also possible that plant nutritional regimes had been so affected by changes in microclimates or soil fertility that acceptability to sheep was altered over the four or five decades of pastoral use.

What successive Commissions failed to do and what Cockayne, father and son, also failed up to 1920 to do in their stock-taking and assessment of the traditional pastoral industry was to take proper account of potential alternative explanations for the physiognomic condition of vegetation which they observed. It is apparent that part of this deficiency came from a misrepresentation of the vegetation which had awaited the beginning of pastoralism. As indicated earlier in this review, it seems evident that by 1920 Leonard Cockayne had not appreciated the extent of tall-tussock grassland that had previously occupied the sites of low-tussock grasslands which he interpreted to be climatically controlled. His ecologic story-telling had been persuasive but it had not been the kind of story-telling which was amenable to rigorous experimental attempts at falsification. Nor should Leonard Cockayne be harshly judged for this failing. No one before or since has demonstrated the same compass of vision and comprehension in telling the story of New Zealand plants and vegetation. As Thomson (1983) has pointed out, the great bulk of his botanical and ecologic work was carried on from his modest private income and was supplemented by periodic commissions from government. His hopes of appointment as Government Botanist were never fulfilled.

So far as Alfred Cockayne was concerned as Government Biologist in the Department of Agriculture, careful interpretation in the second decade of

this century of how the tussock grasslands came to be in their present poor condition was scarcely their principal concern. More in keeping with their mandate was to set out on their revegetation of depleted lands. This path was embarked on with some vigour from 1910 in the Mackenzie country and in Central Otago and, as we shall see in the next section, was soon to involve Leonard Cockayne in a new and important role.

If the story-telling inferences of either Cockayne had consistently demonstrated the full gravity of the ecologic impact of fire and grazing on the tussock grasslands, then it is possible that such catch-cries as "insecurity of tenure" and "compensation for improvements" would not have attracted quite as much attention from runholders and successive Commissions as they did.

"Insecurity of tenure" entered into the mythology of high country pastoralism by dint of constant repetition. I have acknowledged it as a feature of early pastoralism in particular (O'Connor, 1978, 1980; O'Connor and Kerr, 1978). It has even entered international literature of conservation as one of the named concerns in the "main thrust of the recommendations of the 1920 Commission" (Mather, 1982). The frequent allusion to "insecurity of tenure" in that international commentary is somewhat misleading. Blake et al. (1983) have shown from their careful review of legislation that "insecurity of tenure" may have been exaggerated as a primary cause of land abuse or of failure to carry out improvements when they were warranted. Although legally ensured continuity of tenure was available, including the right to freehold, long before the much vaunted Land Act of 1948 and even before the 1920 Commission, feelings of insecurity may have arisen from a different cause. Market uncertainty for the staple wool product was probably a factor. Snow risk has always been acknowledged. Probably of most significance for many pastoral enterprises was their economic situation, unless they were well-established on terrain favourable to sheep-rearing and wool production. The picture assembled from snippets of information on the Mackenzie country, for example, in Dunbar and Hughes (1974), Walls (1966), Norton (1951), Vance (1965), and Pinney (1971) is that the early decades of the twentieth century were characterised by a low-returns, low-cost pastoral frugality. It is not surprising that many of the newer and smaller runs failed financially and were resorbed into the larger surviving properties (O'Connor, 1978).

The rabbit menace constituted a much more serious threat to security of livelihood from pastoralism in virtually all South Island high country except the Waimakariri. "Allowing rabbits to become extremely numerous" was clearly identified by the 1920 Commission as "the most potent of all" the causes of "deterioration and ultimate depletion of the grassland". The 1920 Commission summarised the other causes as: "burning the tussocks, especially at the wrong season of the year"; "overstocking with sheep"; "continuous grazing for seventy years without attempt at improvement"; and "the tenures under which the land has been and is held, and some of the conditions of such tenures." Rabbits were increasingly recognised by scientists and administrators as well as pastoralists to have compounded the effects of any overstocking by sheep. However, as Zotov (1938) suggested and the chronology of sheep decline and rabbit increase in Central Otago would indicate (O'Connor 1980), these two populations, sheep and rabbits, were interactive and interdependent. Not only were sheep flocks greatly reduced on many runs as a consequence of rabbit infestations but as current reviews (Kerr et al., 1987) indicate, change of upland habitat by fire and overstocking with sheep may well have facilitated rabbit population increases. A review of rabbit ecology by Gibb and Williams (1987) suggests such increases arise from enhanced survival of young,

where induced habitat changes interact with climate, soil, disease and predators.

The inevitable conclusion from this reflection on the stock-taking of the 1920 Commission is that administration and collective management of the pastoral industry attempted to continue in their established ways for more than 70 years without any formal attempt to monitor range condition, despite the fact that they had the benefit of useful initial reconnaissances of vegetation and despite the existence of annual sheep returns filed by sheep owners. No attempt seems to have been made to provide any continuing research service within the land-administering body nor does any effort appear to have been given to provision of any analysis of livestock or any other statistics for any of the land Commissions in 1905, 1910 and 1920. The 1920 Commission clearly turned to account the presence within it of the expert Dr Leonard Cockayne. In the 1880s the Crown Lands Department had published a manual of potential plant introductions (Mackay, 1887). Between these two periods the land administering body apparently made little attempt at promoting or using science despite its inheritance of an early tradition of enquiry from surveyors such as McKerrow.

It appears now that there is no reason why county data and trends such as are shown in Figures 3 and 4 could not have been collated and derived up to 1920, just as I derived them for Vincent and Lake Counties in the 1950s. Sheep numbers for each year on individual runs which were compiled in 1960s for all Canterbury runs by Walls (1966) could have been equally well done up to 1920 by a land-administering agency. It is evident from the pioneering work in this field by A.H. Cockayne (1916) that such possibilities were recognised. We can only speculate now on the possible consequences of such simple economic assessments. They could have indicated to the 1920 Commission that the pastoral industry was suffering from a pasture deterioration problem of some extent and magnitude as well as the deterioration and depletion problem of Vincent County. The consequence could have been an earlier correction of our misrepresentation of our past, an earlier understanding of what early changes had been induced in the grassland vegetation and perhaps a more thorough effort at restoration and redevelopment.

In an earlier review of the literature on burning tussock (O'Connor and Powell, 1963) some emphasis was given to the apparent significance of the vegetation linkage between fire and soil erosion that was first indicated by Zotov (1938, 1940). Petrie (1912) had recognised soil erosion as a consequence of vegetation depletion but the 1920 Commission, like Leonard Cockayne, concentrated concern on vegetation change rather than any consequent soil erosion. I now regret the emphasis I previously gave to issues other than vegetation change. Why do I give so much attention to the case for early overstocking of the grasslands and to the argument for inability of those grasslands to support their early livestock load? In successive papers (O'Connor, 1980, 1981, 1982), I have lamented that soil erosion rather than vegetation change had become in more recent decades the politicised central issue of pastoral land use. In our efforts to bring erosion, both natural and induced, into a better perspective e.g. O'Connor (1976a, 1980, 1984), Whitehouse (1984), it is possible that we fail to give sufficient attention to vegetation change itself. Especially we should attend to those changes in vegetation which are likely to be reflected in lower livestock supporting capacity. Changes in livestock load on unimproved range which show an overall trend over time deserve our attention as indicators of vegetation change, independent of short term climatic or market fluctuations (O'Connor, 1980, 1983). Departures or variations from such long term trends may themselves provide valuable indications of the influence of such short-term climatic or market fluctuations (O'Connor, 1980). As we shall see from a later period in the history of land administration and

of science, the pastoral economy and the vegetation itself have been the sufferers because of our misplaced emphasis on erosion.

The development of agronomy

As a result of assessments of pasture depletion on the Mackenzie Plains and in Central Otago (Macpherson, 1910), the Department of Agriculture began a series of agronomic experiments aimed at revegetation (Macpherson, 1910a). In the Mackenzie country Macpherson (1911) reported on the early success of sowings of cocksfoot, prairie grass, sheep's burnet, white clover, lucerne and the like at both Haldon and Sawdon Stations. In the same paper he reported the establishment of wider varietal tests at Earnscleugh in Central Otago. Macpherson (1912) reported in more detail on the Earnscleugh experiments and in the following year (Macpherson, 1913) he summed up of the two districts:

> "In the Mackenzie country spring sowings have done better, while in Central Otago autumn sowings have done better. The experiments so far go to show that surface sowing of these lands would be a waste of money; that surface sowing and harrowing would give results very little better, and that even cultivating the land with a cultivator, harrowing, rolling, sowing the seed broadcast and harrowing afterwards does not give nearly as good results as when the seed with the same cultivation and work is drilled in. The grasses, clovers and deep-rooted plants which give the best results so far are tall oat-grass, awnless brome-grass, cocksfoot, prairie grass, Agropyron repens, Phalaris commutata, Festuca dumetorum, rib-grass, Bokhara clover, white clover, underground clover, lucerne, sheep's burnet, chicory, sainfoin and yarrow."

Such work well and promisingly begun at these stations and at Whalesback in 1911 and Morven Hills in 1913 was interrupted by the First World War. In a brief report (Macpherson, 1920), the persistence of several sown species ungrazed but unattended at Whalesback since 1914 was noted: tall oatgrass, bent-grasses, fescues, red, alsike and wild white clovers as well as sheep's burnet, yarrow, chicory and Peruvian and Hungarian lucerne varieties. In the early 1920s the main emphasis on revegetation research in the Department of Agriculture was transferred to Central Otago (Cockayne 1922, 1922a, 1922b). Nevertheless, the Mackenzie work at Haldon and Whalesback was continued at a less intensive level (Ward, 1923) and evaluated by McGillivray (1929), reinforcing the species list above from the 1920 observations of Macpherson, emphasising the sward-making characteristics of wild white clover "with Poa pratensis and in other parts with yarrow", and also noting the prolific growth of zigzag clover (Trifolium medium) established by transplants in 1924. McGillivray (1929) also observed the progress in natural regeneration in the Mackenzie country grasslands, attributing the improvement to a reduction in rabbits since 1921. However, the accompanying 20 percent increase in numbers of sheep that he noted for the whole County from 1922 to 1928 was not matched within the Mackenzie Basin. Individual run data of Walls (1966) reveal less than eight percent increase in sheep for the same period on all Mackenzie Basin runs. It is noteworthy that most of this total increase occurred on large runs in the eastern sector which had been badly affected by rabbits (Pinney, 1971). Clearly McGillivray saw evidence in the Mackenzie of a reversal of the trend described about a decade earlier for Otago by McCulloch (1917), Cockayne (1919c) and generally by the Commission on Southern Pastoral Lands (1920).

In 1918 Leonard Cockayne had been commissioned by the Department of Agriculture to conduct an economic investigation of the montane tussock-grassland of New Zealand. He continued this project until 1922 when he was already 67 years of age and in poor health (Thomson, 1983). The full story of this remarkable phase of

Cockayne's career, as an ecological agronomist and pasture scientist, has not yet been told. It is noteworthy that apart from his study of alpine plants in a freezing chamber (Cockayne, 1898) this includes the only experimental work which he reported. His introduction to the project (Cockayne, 1919) described some of the problems to be attacked and indicated Marlborough and the Waimakariri as especially suited for certain phases of the work ahead. He noted that in many cases botanical names referred to aggregate species and he recognised the need to "segregate the various races of palatable grasses and other herbs of the tussock-grassland" and to assign definite names to such unnamed races. He also identified the problem of measuring palatability, a topic on which he was to report some progress (Cockayne, 1919b, 1920, 1920a, 1920b). His introduction also briefly discussed the burning question and the rabbit question, outlined an ambitious approach to the understanding and use of variation in Danthonia pilosa and discussed the practicalities of oversowing and of cultivation.

Apparently, however, as an outcome of his report on depletion (Cockayne, 1919c) he was authorised to carry out a series of regrassing experiments. Instead of the work he had nominated earlier for Canterbury and Marlborough, these experiments were located in 12 exclosures fenced in the summer of 1919-20 on Northburn Station in Central Otago. The austere figure of Dr Cockayne F.R.S., pedalling his cycle from Cromwell Railway Station to Northburn, became familiar to the residents of Cromwell and Lowburn. In a few years the Cockayne Plots on Northburn slopes, from 250 m to 800 m, were to become abiding landmarks for all to look up to. Cockayne (1921a) had reported the effects of spelling from grazing following prolonged overgrazing of semi-arid grasslands. In this new series of papers (Cockayne, 1922, 1922a, 1922b) he described and reported the early results of a remarkable series of experiments which examined the interaction of season and method of sowing of a wide range of cultivars with altitude, aspect and remnant vegetation.

At the outset Dr Cockayne had formed a committee with an officer of the Department of Agriculture, J.L. Bruce, and two local runholders, R.K. Smith of Morven Hills and D.S. Middleton of Northburn. In November 1922, he invited these three to inspect the experiments and report on them to the Director-General of Agriculture. Their report (Middleton et al., 1923) is an eloquent testimony to Cockayne's skill and understanding. They noted the establishment by surface-sowing, generally as effective as with raking at every altitude and aspect except on the worst wind-swept ridges, of perennial pasture plants, especially lucerne, yarrow, chicory, sheep's burnet, cocksfoot, tall fescue, Chewings fescue, perennial ryegrass and couch-grass. They noted that regeneration of native plants had been rapid on sheltered plots at higher altitudes, slower on plots lower and with greater exposure. They also noted that complete depletion persisted outside the netted areas. Accordingly they concluded with conviction that (a) depletion was proceeding rapidly in all the dry area of Central Otago under existing conditions; (b) that improvement was impossible without exclusion of rabbits and subdivision to allow a regular system of spelling the country; (c) that rapid and substantial improvement could be effected by surface-sowing if rabbits and sheep were excluded and systematic spelling practised; (d) that by spelling alone, improvement would occur but more slowly.

These experimental areas have been inspected, manipulated, supplemented and reported on in some detail by Tennent (1935), Calder (1938, 1944), Lunn (1951) and Hercus (1954). For many decades they remained an ironic anomaly on the dry hillsides because the continuing rabbit plague and the financial stresses on many runholders ensured that there would be no

emulation of them on a large scale. More recently they have been the subject of periodic monitoring for herbaceous components and for the conifers and eucalypts which were planted in them at the outset (Douglas, 1970; Wills and Begg, 1987). Douglas turned to account the differences in grazing regime which had resulted from periodic changes in fencing and he interpreted the vegetation history as follows:

> 1920-30: Ungrazed plots dominated by palatable species (e.g. lucerne and cocksfoot).
>
> 1930-1956: Grazed plots dominated by unpalatable and rhizomatous species (e.g. tall oat grass, Poa pratensis, Chewings fescue, yarrow and some zigzag clover).
>
> 1956-1970: Ungrazed plots with significant establishment of forest species (seedlings from original planted trees, especially Pinus ponderosa, P. nigra, Eucalyptus tasmanica; rhizomatous and unpalatable species persist, together with some palatable ones." (Douglas 1970, p.23).

According to Wills and Begg (1987), there has been further variation in grazing regimes subsequently because some plots are now completely open, some no longer stockproof, some stockproof but open to rabbits, some closed to both livestock and rabbits. They recommend that the plots be managed for further more systematic monitoring in the future. They now constitute the longest-running series of periodically-monitored vegetation studies in the grasslands of New Zealand. The highest plots have been included in an area of pasture development following the more modern practice of oversowing with clovers and sulphur and phosphorus topdressings. One of them is now completely occupied by pine trees.

Although there are many instances throughout Central Otago and the drier parts of the Waitaki and Awatere catchments where previously severely depleted country has been revegetated in the last 20 years by pastoral farmers, especially by such techniques as overdrilling of lucerne and sometimes by sowing of cocksfoot, tall oatgrass, and sheep's burnet, Cockayne's lessons have remained unpractised on the broad scope of semi-arid range which has frequently remained "rabbit-prone" (Kerr et al., 1987) and revegetated only by volunteer and sometimes short-lived plants.

Revegetation agronomy remained one of the major concerns of the Department of Agriculture in the tussock grassland regions for several decades (O'Connor, 1980a). In drier parts of Otago it was extended to Galloway, Pisa Flats, Hawea and Ophir (Calder, 1938, 1944; Hercus, 1954a) and in Canterbury to Riversdale and Broken River in the Waimakariri (Sewell, 1950, 1952), as well as to runs in Marlborough. Revegetation agronomy likewise became the concern of soil conservation personnel at Tara Hills in the Waitaki, in Central Otago, Southland and Marlborough (van Kraayenoord, 1978; O'Connor, 1980a). Revegetation agronomy, first by Wilkie, then by Simpson (1957) and by Simpson and Moore (1955) also became an integral part of the sustained and carefully monitored studies of changing vegetation of Molesworth from 1944 to 1971 (Moore, 1976).

In the years leading up to the discovery of sulphur deficiency affecting the establishment and growth of clovers in tussock grasslands (Lobb, 1953, 1953a; Lynch 1954), most of the agronomic experimentation to improve them had been done without fertilisers. Saxby (1940) had successfully introduced clovers into tussock grasslands by oversowing with fertiliser, but even 10 years later (Saxby, 1950) he questioned the desirability of clover introduction into tussock grasslands even if it could be widely demonstrated to be feasible. Likewise for the steeper tussock hill country he foresaw (Saxby, 1956) that decisions would have to be made whether to aim at a

> "topdressed grass-clover association

which may or may not be maintained indefinitely, or the introduction of exotic grasses or the improvement of the native species" (p.137).

In historic fact, all three options have become fused as we shall see in a later period.

Development of natural sciences

The pace of natural biological sciences showed no noticeable quickening in the tussock grasslands in the period following the 1920 Southern Pastoral Lands Commission. Bathgate (1922) contributed some valuable recollections on the early vegetation conditions of the Manuherikia Valley and the Dunstan Gorge in the 1860s and a more detailed account of changes in the avifauna as well as the vegetation in coastal Otago. Allan (1927) presented a careful and lucid account of the grasslands and other herbaceous communities of Mt Peel. He had drawn on this exercise for his exposition of the study of open communities in high mountain areas (Allan, 1926), widening the concept of succession to include physiographic succession as occurred on shingle-slip and alpine fell-fields. In the same volume Cockayne (1926) had also traversed some of his field study methods in tussock grasslands and (Cockayne, 1926a) his use of naturally occurring "unpremeditated experiments". Like Allan (1926), Cockayne (1928) found occasion in his revised second edition of "The Vegetation of New Zealand", to distinguish "shingle slip formations" from fell-fields and to be cautious about the interpretation of observed fell-fields since "much is merely induced through the burning of tussock grassland or Nothofagus forest" (p.295). Likewise Cockayne (1928) gave a fresh emphasis to snowgrass associations:

> "Snowgrass associations are extremely common in South Island and appear in their greatest strength in the wet mountains but much vegetation where Danthonia Raoulii var. flavescens is abundant must be referred to herb-field. On the dry mountains and even in the fairly wet South Otago district much of the community has been wiped out by fire and the large area remaining is usually greatly modified. Originally in South Otago as may be seen even yet, snowgrass associations descended nearly to sea level" (p.308).

For apparently the first time, Cockayne (1928) recognised explicitly the role of burning in making short tussock-grassland out of tall tussock-grassland. Thus he writes of tall tussock-grassland:

> "At the present time it is most common in the subalpine belt but originally in the drier mountains it descended to the montane belt, nor can it readily be separated from lowland tall tussock grassland, except for convenience. Burning, however, quickly spells the death of the large tussocks and the smaller tussocks take their place, such replacement making a community not to be distinguished from one that is virgin, except by its history". (p.306) (Emphasis mine.)

It is clear, however, from the above citation that Cockayne (1928) was not about to recant totally on his earlier interpretation of low tussock-grassland as a climatically-controlled formation. He was, however, acknowledging that at least some low tussock-grasslands could have been derived from tall tussock-grasslands.

Cockayne (1928) remained committed to a belief in the "optimality" of New Zealand life-forms for New Zealand conditions. This belief was shown especially in his vigorous exposition (p.361) of the competence of the primitive and uninterfered-with vegetation to resist invasion by exotics. Perhaps strangely, he made this assertion under the heading of indigenous-induced communities, "purely New Zealand in facies but unknown in the primitive vegetation". Under such a heading he described the Danthonia pilosa grassland of north-eastern South Island as a new formation formed from low tussock grassland.

Under the same heading, but noting that there are gradations from exotic-induced to indigenous-induced communities, he described as the "induced steppe" of particularly dry parts of the South Island not only the scabweed community but its gradations to other modified associations on damper or higher ground. He noted that the flora of the whole Central Otago induced steppe consisted of some 91 species (54 indigenous, 37 exotic) about 40 of which were common, but seldom more than 30 (indigenous and exotic) occurred on the worst depleted ground.

Leonard Cockayne had, in effect, exercised his own form of dominance over ecologic interpretation of the tussock grasslands, as for the New Zealand vegetation generally. Thomson (1983) has noted this dominance from the commentary of one of Cockayne's contemporaries. His potential contribution to the revegetation of Central Otago's man-made deserts was never realised, despite the practicality of his approach and his careful attention to information transfer and independent evaluation and validation. His agronomic achievement was technologically enormous but it had no extension in practice because the agents of desertification, sheep and rabbits, remained at work. Their dominance derived from economic conditions of pastoralism which neither Cockayne nor any other party appeared to investigate in any public way.

In contrast with this situation, Cockayne's potential contribution to the improvement of use of the remaining tussock grasslands was limited by his own strong belief in their optimality, in their being the best-suited plants to the New Zealand mountain environment. In view of Cockayne's dominance, this situation might well have persisted for some decades, were it not for the journey of V.D. Zotov.

As the fruit of a nine-week tour of the tussock-grasslands, Zotov (1938) composed a quite remarkable paper, reinterpreting the grasslands with some subtle but important differences of emphasis from Cockayne. Zotov's work was strong on field impressions and observations, light on hard, relevant climatic data, almost as light (Zotov, 1938a) on reliable functional relationships between vegetation and climate. Later, more meticulous work has shown that Zotov (1938) was, at several times, quite uncanny in intuitive insights. Whereas Cockayne (1928) had considered only the depleted ground of Central Otago to be induced steppe, Zotov (1938) considered most of the grasslands below a natural upper timberline to be "induced steppe", but as he pointed out, and as Allan (1946) clarified in an elegant essay, Zotov's "induced steppe" had a quite different meaning.

For Zotov, induced steppes were interpreted as early successional stages which without interference "would gradually pass into scrub and finally back into forest which is the climax formation naturally occurring under existing climatic conditions". As Allan (1946) pointed out, Zotov's "true steppe" was the equivalent of the "low tussock-grassland of semi-arid habitat" of Cockayne (1928). Zotov delineated its natural extent in Vincent and Maniototo Counties of Central Otago and over the floor of the Upper Waitaki basin. Much of this was now, in his parlance, reduced to semi-desert condition.

For the rest of the tussock grasslands below timberline, Zotov saw them as an induced vegetation, resulting from the destruction of forest by fire. This was not quite revolutionary, but it was certainly full circle from a theory of climatic control of the grassland formation and of optimality of the taxa for the conditions. As Allan (1946) observed, Cockayne had pointed out that considerable areas of tussock grassland owed their origin to the burning of forest (e.g. Cockayne, 1921b). Cockayne (1910) however, had specifically excluded the relevance of ancient totara forest (Speight, 1910) to

the succession of forest to grass after fire. Now in the approach of Zotov, for the first time since Buchanan, we had a botanist in New Zealand tussock grasslands give as much attention to the Podocarpus hallii logs found on hillsides in Canterbury and Otago as to the tussocks which grew among them. In this respect Zotov (1938) was potentially some 10 or 20 years ahead of his time. Not only was he indicating that the existing climate conditions could support forest but he was, by implication, inviting his fellow scientists to join him in testing this story-telling about vegetation and climate. For some such as Holloway (1954) and Raeside (1948), the emphasis was to be an alternative story-telling of climate change. For Molloy (1962) and Molloy et al. (1963), emphasis was on discerning from subfossil forest remains the extent of forest distribution and the chronology of its destruction by fire.

This science story-telling about climate also had implications for land use. If this was a forest climate then the corresponding utility story would be that the climate could support pasture growth like other forest climates in New Zealand. As we shall see, it was to be users of pastoral land as much as scientists who put such new stories to the test.

Zotov (1938) made some other shrewd observations and inferences about the composition of grasslands of the "true steppe" kind. Where such grasslands were relatively inaccessible to livestock they were characterised by one or another variety of Agropyron scabrum. In Zotov's own words: "Instead of the Festuca novae-zelandiae giving the very characteristic aspect to the 'tussock-grassland', it was very probably of much less importance in the primitive associations." (p.220) In this he was endorsing some of the early writers cited in this essay and giving a different emphasis from Cockayne who by frequent repetition had almost succeeded in making Agropyron scabrum into a "tussock". It was left to Connor (1950, 1954) to recognise and distinguish the infra-specific units within Agropyron scabrum. Of the 12 groups Connor (1954) studied, only one (Group Otago) was of erect, tufted habit, approaching the tussock form. Although sympatric with two other groups in damper areas and around the margins of semi-arid Central Otago, this Otago group, strict, blue, with spikelets at wide angles from rachis, and with long anthers, was later found worthy of specific status as Elymus apricus (Love and Connor, 1982; Connor, 1985). The remainder of New Zealand Agropyron scabrum is now Elymus rectisetus.

Zotov also served to modify or confirm some of the myths which scientific writers had been cultivating concerning the pastoralists' reasons for burning. Zotov (1938) recognised that pastoral settlers had begun "to use fire very extensively, with the set purpose of clearing the country of tumatakuru (Discaria) and speargrass (Aciphylla). Further the grasses themselves were burned to induce more palatable young growth. Introduced grazing animals since the arrival of European colonists have grazed heavily all palatable herbage." (p.221) He proposed that this deliberate burning of grass was an acquired rather than primary characteristic. He surmised: "Soon after the initial fires it was discovered that the young growth of such otherwise unpalatable species as hard fescue (Festuca novae-zelandiae) is of relatively high palatability. This discovery eventually became the real reason for the establishment of the practice of periodic burning". (p.224) It was a probably correct statement but perhaps poorly exemplified. It was initially Sewell et al. (1954) who recognised some of the implications of use of fire in the snow tussock grasslands to make them more manageable. It was largely through the work of Connor (1961, 1964, 1965, 1974) that we learned how the practice of burning tall-tussock grassland had made possible the management of a short-tussock grassland. Pastoralists had probably learned it nearly a century before.

Some of Zotov's intuitions were therefore found to be prophetic, some were a little wide of the mark. Opinion and practice surveys concerning burning (e.g. Cumberland, 1945) have not themselves been clear in revealing either the real motives or the real effects of burning as a land use practice in tall tussock or any other vegetation. Detailed studies of particular sites (Barker, 1953) and even experimental treatments (O'Connor and Powell, 1963) have been necessary before even the primary questions of the Southern Pastoral Lands Commission of 1920, referred to earlier in this essay, have begun to be answered by science.

Zotov (1938) was important also for his observations and intuitions concerning the connections between vegetation and soil erosion. Burnett (1927), a born and bred high country pastoralist as well as a profound conservationist, had affirmed in no uncertain terms his unshakeable belief in slope denudation by burning as the cause of disastrous flooding in the 1870s. Zotov should be given the accompanying credit for propounding that "soil erosion in the drier areas of the South Island is closely bound up with the progress of depletion, and its control with the means of regeneration of a vegetative cover." (Zotov, 1938, p.237)

Zotov was essentially correct in this assertion concerning drier parts of New Zealand, and in his careful description of gully erosion and wind erosion, the latter especially following soil frost action in denuded soils. He was perhaps less correct in apparently representing the Craigieburn Mountains and the Broken River Basin as coming within the ambit of the above-cited proposition. They were clearly areas outside his climatic zone of true steppe. He noted shrewdly enough:

> "Slip erosion is not infrequent on the wetter hillsides of Canterbury and Marlborough and to some extent, Southland. Whether this is any more extensive than it would have been under natural conditions is not quite clear. It is certain, however, that under present conditions there is little likelihood of their ever being covered by soil again".

Zotov's work contributed to the scientific report of the Committee of Inquiry (1939). For a Committee which met only twice and that within the space of a month, the output of this committee was substantial. It had been given as its brief:

> "To inquire into and report on measures necessary for the preservation of vegetation in New Zealand, with special reference to the incidence, control and prevention of land erosion".

In view of the legislation, programmes, alleged propaganda and counter propaganda which ensued, it is as well to record its general finding and recommendation:

> "Reviewing the whole body of evidence before it this Committee is convinced that soil erosion in many areas has reached a serious stage, and if uncontrolled will accelerate rapidly.
>
> "The Committee, however, deprecates an alarmist attitude. As was inevitable in the development of a young country, mistakes have been made, but in few places is the damage wholly beyond repair.
>
> "Permanent production must ultimately be based on a more stable vegetative cover, combining in due proportion forest, shrubland, and grassland. Only so can the forces of erosion be adequately controlled and water supplies necessary for the closer development of the country fully protected.
>
> "For these reasons this Committee recommends that - Statutory and administrative measures should be taken at the earliest opportunity to inaugurate a programme to handle the serious soil-erosion, soil-conservation, and land-utilization problems that now face us. In such

> a programme the most effective factor will be the preservation and establishment of a stable vegetative cover in which forest land, shrubland, and grassland have most important parts. Further, such a programme should include the active collaboration and co-operation of foresters, agrostologists, botanists, agriculturists, engineers, and soil technologists". (p.37)

These findings and recommendations reflect the best minds in plant, soil, and earth sciences, pure and applied, in New Zealand in 1939. They betray a clear belief that the problems were controllable. They seemed couched to defuse rather than to inflame or assign blame. When the topic was resumed after six years of costly foreign war, the belief in controllability was now dominant. An organisation had been established with both central government functions and regional or catchment functions (McCaskill, 1973). Cumberland (1944) had presented a reconnaissance survey of soil erosion in New Zealand in which blame for past failings and belief in urgent action for control were both clearly evident. Gibbs and Raeside (1945) had presented a reconnaissance survey of soils and erosion in the high country of the South Island. It was more quantitative in its approach, but remained somewhat simplistic in its interpretation of relationships between vegetation depletion and erosion, and between erosion and pastoral practices. Sewell et al. (1954) represents perhaps the best statement of understanding of high altitude tall-tussock grasslands reached in this long middle period of pastoral degeneration. In summary, it found that there was "no justification for retaining the high altitude snow-tussock grassland in pastoral use until some method of revegetation is found."

In reviewing the growth and development of natural sciences during the pastoral degeneration period, we can therefore recognise that by 1950, quantitative studies of vegetation had been singularly rare, and interpretative studies had ranged rather widely without ever coming to defined levels of confidence. The patient work of biosystematics and taxonomy on which each ecological worker recognised his or her complete dependence had itself become indigenised through the work of Kirk (1899), Cheeseman (1906, 1925) and Allan (1936) and also with his colleagues in the "Flora", at that stage unpublished. Ecology, whether oriented to understanding what sorts of vegetation we had, or how better they might be managed or used, or indeed how they might be improved as pasturage, remained stymied until these "systematic" obstacles were removed by such works as Allan (1961), Connor (1954, 1960), Zotov (1963, 1970) and Moore and Edgar (1970).

Soil science in tussock grasslands which had begun well in the survey of irrigation districts of Central Otago (Ferrar, 1929) had been extended with the work of Gibbs and Raeside (1945) and by regional surveys which were collated in Soil Bureau (1968) as General Survey of Soils of South Island. Geomorphologic and hydrologic research remained dormant except for the reconnaissance and regional interpretation of Cumberland (1944, 1944a) and the collation of information in the report of Committee of Inquiry (1939).

The interaction that didn't

The establishment phase of pastoralism had demonstrated an initial partnership of scientific inquiry and utility inquiry. By the end of the establishment period there were clear signs of divergence between the two kinds of stories. If pastoralism was going to respond positively to the changes in ecologic and economic conditions which it was to encounter over the next 70 years from 1880, it would need a new and positive interaction between science stories and utility stories. That interaction was doomed to a long postponement.

In a review prepared for a grazing industries symposium held at the 2nd

International Range Congress in Adelaide in 1984, an attempt was made (O'Connor et al., 1986) to summarise the main features of administrative and managerial responses to changes in ecologic and economic conditions following the early pastoral establishment phase. Managers and runholders on arable lowlands had responded by mid-1870s to declining range condition and economic stresses by sowing pastures and crops. Runs on lowlands were converted to large farming estates supplying agricultural and pastoral products for expanding domestic and international markets. The threat of dismemberment of such large estates under the Liberal Government which came to power from the 1889 election, the creation of new credit facilities, and the founding of the Department of Agriculture, all combined to replace lowland pastoralism with mixed farming.

In the hill and high country, even where the terrain appeared physically arable, pastoralism was exempted from the initial public zeal for land reform. Certainly the climatic rigours of the high country acutely affected political and commercial perceptions. The 1895 snowstorm promoted a Pastoral Tenants' Relief Act from a reforming government which professed that the Crown's interest in high country pastoral lands would suffer if runs were not restocked (O'Connor, 1978; Burdon, 1938).

Continued pastoral deterioration followed the debilitating effects of expanding rabbit infestations and recurrent use of fire. It produced commercial anxiety, even disaster in some cases, and prompted periodic calls for new conditions of tenure or the like. As has been indicated in preceding sections, there was no sustained or fundamental scientific vindication, amendment, or denunciation of the pastoralist ways during the whole six decades from 1880 to 1939. Science itself had become oscillatory and irrelevant to practice.

Indeed, there is some suggestion that opinions of scientists such as Leonard Cockayne might have been given too much credence or attention. Thus McCulloch (1917), writing in the Journal of Agriculture, represents an important convergence between practical pastoralist and scientific opinion:

> "My suggestion is, to put it briefly, that practical pastoralists never attempt to replace the native grasses where those are in abundance on a similar type of country, but are quite content to profit by nature's bounty, knowing from their practical experience that economically the position cannot be improved." (p.293)

The same author proceeds:

> "The writer would draw the attention of all those concerned to the fact that undoubted evidence exists that, as a result of natural selection for centuries past, the vegetation now found in our native pastures is in many ways likely to be the best adapted to withstand the rigours of the naturally arid climate of the country in question."

Why did McCulloch so archly address all those concerned? It is easy to assign meaning to such comments that was not intended, or to fail to discern now some meaning or import that was intended at that time. As has been pointed out in a study of the evolution of the Upper Waitaki pastoral community (O'Connor, 1978), this period of the 1st World War was one of intense activity in pastoral subdivisions in both the Mackenzie and Omarama districts. The public clamour for farmland to be made out of pastoral runs was loud and vigorous. Fifteen farms for soldier settlement, as well as 22 runs, either small grazing runs or pastoral runs, were partitioned from Benmore station in the Upper Waitaki in 1916. The fact that by 1930, these 37 management units were reduced to 28 and by 1970, to 20, might seem to show the wisdom of caution against farming intensification. Was the same caution appropriate from Saxby in 1950? The question remains open.

The important features of this sustained period of pastoral deterioration and stagnation from 1880 to 1950 are that ecologic science was sporadic, scanty and opinionative, while socio-economic science was apparently minimal. Despite the assertion of "economic investigations", seldom if ever was economic fact-finding and inference joined with ecologic inquiry, either into the condition of the grasslands or the condition of their pastoral enterprises. The agronomic science which emerged as perhaps Leonard Cockayne's outstanding contribution to the science of New Zealand grasslands remained doomed to ineffectiveness for want of a charismatic campaigner against rabbits. The equally significant discovery by Saxby (1940) that clovers could be introduced into tussock grasslands and that by Tennent and Duff (1929) that such legumes responded to sulphur were to remain as "blocked choices" until the wool boom of 1950s.

So long as the variety of physical and socio-economic conditions in the pastoral hill and high country remained unwritten and uninvestigated, it was to be expected that pastoral criticisms such as those of Cumberland (1944b) and Raeside (1956, 1960) would be strong on generalisation. It was equally likely that they would meet dogged, shrewd and even bitter defence of a way of life (Royal Commission, 1945; Chapman, 1954, 1956; McLeod, 1975).

I had proposed (O'Connor, 1980) that Riney (1964) by his postulate of eruptive behaviour of animal population after colonisation would offer a model that could accommodate the pastoral industry on native New Zealand range. I was conscious that this model owed a debt to Riney's (1956) own approach to New Zealand tussock grassland systems and to Holloway's (1950) previous observations of deer in the forests of Western Southland. Caughley's (1970) exposition of such a model for tahr in central alpine New Zealand was less than ideal, because that population was perhaps confined by a combination of varied terrain and hunting pressure.

I looked in the calculated livestock load on unimproved range of Vincent and Lake Counties for "an eruptive phase, a period of levelling off, a decline, and a final phase of relative stability". It was evident from that examination (O'Connor, 1980) that in absolute terms (Fig. 12.3, p.208) and in numbers calculated on unimproved range (Fig. 12.4, p.209), stock units declined from 1881 to 1905. The "relative stability" which might have been expected to ensue in calculated numbers on unimproved range was found to be replaced by an oscillating but generally downward trend from 1905 to 1950.

When sheep numbers on high country runs have been since examined over approximately the same period from 1900 to 1950, as for Mackenzie runs (O'Connor, 1976), Canterbury "gorge" runs (O'Connor et al., 1986), and all Canterbury runs (O'Connor, 1983), a generally similar oscillating but downward-trending sheep population has been recorded. The present data in Figure 4 allow the fairest comparison of calculated "total livestock on unimproved range" for other counties with that for Vincent over the whole period. The relative stability had not everywhere emerged even over 70 years.

Clearly Vincent's collapse in "range livestock numbers: in the late 1940s and early 1950s is unusual in its severity and is not unrelated to the gravity of the rabbit problem. The low proportion of total sheep equivalents carried on such range at that time is a feature of all counties studied. Neither the science stories nor the utility stories which had been told over the previous half century or more were very satisfactory by 1950. It was not going to be much consolation to any story-teller to be confirmed that he or she had been right. In effect, more than the emperor was lacking clothes!

Pastoral runholding had been served scantily by science since 1880. It had not been very well served by commerce, public administration or any other

party. The end of World War II was hardly a time for scoffing at either the fruitlessness of science or the waste of resources. But if this were true internationally and nationally, so was it true in the high country. By the time that the Depression-induced overstocking had done its worst, and labour shortages during World War II had let rabbits, deer and goats out of control in many districts, reconnaissance surveys of vegetation conditions and soil resources were allowing a new kind of story-telling to be fostered. Matters were about ready for a western-range style shoot-out. It might have been different if the great articles of a new faith had not been solemnly incorporated in law and if temples for the new rites were not being established in catchment districts virtually throught the country. The new faith was the belief that flood control required erosion control, that the upstream cause was responsible for the downstream effects, and that most forms of erosion that we could see in the tussock grassland high country, such as screes, gullies, landslides, solifluction and wind erosion after soil frost, were accelerated erosion as a result of newly-come man and his introduced animals.

The founders of new faiths earn respect. I believe we should give Cumberland the credit for packing and marketing the erosion package to New Zealand. We should give McCaskill the credit for tying the catchment connection. The Sheep Industry Commission (1949) crudely and belligerently challenged the validity of both the package and the connection. The indignation with which such skepticism was rejected by the priests of the new faith in the newspaper columns of 1949 is matched by the devotees of catchment control, even to the present day in agricultural journals or at high country field days.

The maintenance of vegetative cover and conservation of soil resources warranted a better fate in New Zealand than a jehad or holy war. What eventuated was the equivalent of a sectarian brawl in which the only winners have been some of the land occupiers and the regional and national bureaucracies. My lament has been that whereas the native forests have had their lobbies and their champions, there has been little concern or attention until very recently for the fate of the tussock grasslands themselves. Now they are themselves in danger of some new kind of "natural landscape" idolatry that shows little understanding of the nature of landscape and even less appreciation of the character of nature.

If we are to profit from the bitterness of our past experience we had better recognise that the organisational separation of science story-telling from utility story-telling is an effective way to secure irrelevant science and science-free mythology simultaneously. There is no necessary consequence that this situation will lead to social evil. There is little prospect that it will lead to good. In "difficult environments" such separation is hazardous. To appreciate the significance of these propositions it is appropriate to examine the summary record of interacting science and land use in the most recent phase, that of pastoral regeneration.

Science in pastoral renewal

Caughley (1983) considered as Thane Riney's greatest contribution to solving the deer problem his debunking of Cockayne's prejudice concerning the impact of deer on forests. Caughley identified Riney's discovery:

> "that although deer modify vegetation, as everyone well knew, that process does not go on indefinitely. An equilibrium is achieved after about forty years, the vegetation and the deer reaching an accommodation with each other. Cockayne's notion that forests are modified to destruction was false". (p.71).

Degradation or new equilibrium?

Some might have thought that tussock grasslands and herb fields would also be

"modified to destruction" by the grazing of sheep and rabbits. Cockayne apparently did not entertain such a general theory. Such a notion was implicit in Cockayne's writing only so far as the semi-arid grasslands were concerned, and perhaps for the induced "shingle-slips". If some new equilibrium were to be reached as an outcome of fire and grazing on the native grasslands of New Zealand, then it is conceivable that as long a period as 40 years might also be required, as for forests. Riney (1956) had outlined the principles that governed such a zooecological approach to tussock grasslands now occupied by different classes of animals.

It is evident from the great bulk of Cockayne's writings on tussock grasslands that, apart from the man-made desert of Central Otago, he conceived that some kind of new equilibrium had been attained. The adventive elements in the vegetation compensated for the "deterioration" by which palatable elements had been lost. How else was his frequently expressed idea of "relative stability" of livestock numbers on tussock grassland to be interpreted than as a sign of a new dynamic equilibrium, as later postulated by Riney? But what of situations, as sometimes indicated in Figure 4, where "relative stability" in the post-eruptive phase was replaced by oscillating but generally downward-trending sheep equivalents? Was it not possible that a permanent degradation of the grassland resource base had occurred. If this had occurred, then it is conceivable that 40 or 70, or even 100 years might be insufficient for "relative stability" to emerge. Was it not also possible that even where "relative stability" seemed closest to occurring as in Mackenzie County, it was because large areas of short grasslands were being changed to useful "weed communities", while large areas of tall grasslands were being progressively burnt and grazed into "more useful" short tussock grasslands?

Let us summarise the main opinions concerning such a degradation of resources and their potential rehabilitation. Cockayne had recognised such a degradation in semi-arid depletion and sought to compensate for it with the creation of a new resource base by revegetation. Zotov (1938) had indicated a permanent degradation in the form of soil erosion as a consequence of depletion. Cumberland (1944, 1944a) had demonstrated the regional variation in such soil degradation while Gibbs and Raeside (1945) had attempted to quantify its extent and severity. None of these demonstrators of soil erosion had expressed much hope for cure or amendment while pastoral use continued in its existing mode. None of them had offered any new pastoral mode.

The pre-war scientific Committee of Inquiry (1939) had recognised that the agents of deterioration, burning, overgrazing and rabbit infestation and at higher levels, red deer, had to be controlled. It noted that "in places the present methods of rabbit control result more in the farming of the rabbits than in seriously reducing their numbers". It also suggested that "in regrassing depleted areas the re-establishment of the tussock grasses must precede the establishment of the more palatable species". It did allow that experiment might show that the "shade and shelter" effect of the tussocks could be provided by exotic species. In the subalpine belt, it concluded that the only practicable way of improving the plant cover was "to protect it as far as possible from grazing and browsing animals and from fires" (p.35). As noted earlier, this Committee saw most soil erosion as controllable, especially by the "restoration and maintenance of a stable vegetation cover". (p.35)

The short-lived and frequently overlooked, pre-war Sheep-farming Industry Commission (1940) acknowledged the fact of land deterioration, widespread and varied, but mainly in the form of (a) weed invasion, (b) soil erosion (endorsing the Committee of Inquiry, 1939), (c) depletion of soil fertility, and (d) what it termed

"destruction of valuable grassland covering such as chiefly occurs on parts of the high country sheep-farming lands of the South Island" (p.7). This Commission proposed that a Land Utilization Council should be established (a) to classify land subject to deterioration according to its capacity to meet the charges of rehabilitation; (b) to advise the Government as to the way in which lands so classified should be used and as to financial provisions necessary; (c) to advise the Government in respect of any other matter directly or indirectly connected with such land.

In proposing a basis for classification of land, the Commission was noteworthy in recognising that other land uses had a place. It acknowledged that land from which the returns after rehabilitation would not be sufficient in sheep farming to meet the costs of interest, labour and management, might be more appropriately used for recreational, forestry or protection purposes. This Commission also is noteworthy for its advocacy of a "killer" policy for all Rabbit Boards, its urgent recommendation for research, including economic investigations, relative to sheep-farming in the high country pastoral lands of the South Island, and its concern about the lack of authoritative information on "the economics of land utilization and the methods and costs of producing, selling and distributing in sheep farming". (p.11). In short, the pre-war Sheep Industry Commission (1940), like the scientific Committee of Inquiry (1939), saw erosion as serious but controllable by land rehabilitation. It also recognised that such rehabilitation would not always be economic and that sheep-farming on such land was not necessarily the best use of it.

This pre-war Sheep-farming Industry Commission (1940) has no more vehement contrast than the post war Royal Commission into the Sheep-farming Industry (1949). If one speculates as to the reasons for the dramatic difference in attitude between these two Sheep Industry Commissions, one might think of the few years that separated them but of the events which had occurred in those few years. Not only had the nation been deeply involved in the human cost of foreign wars for six painful years. Wool had been fixed at a depressed price as part of "contribution to the war effort". Labour had dissipated in the uniforms of war, with rabbiting neglected for want of labour. But the Soil Conservation and Rivers Control Bill had been passed into law in 1941, under a certain amount of pressure and lobbying from those subscribing to the new faith that "soil erosion is a national menace and catchment control is the answer" (McCaskill, 1973).

By the time the Commission into the Sheep-farming Industry had been reappointed with a new membership and a new royal warrant in 1947, runholders were already alert to the threats provided by the powers of the new Act and of the Catchment Authorities. Such runholders were also concerned with the inequities of rent and administrative treatment with which their landlord, the Department of Lands and Survey, was apparently treating them (McLeod, 1975). But they were also confident that their interests were well represented on the Royal Commission (McLeod, 1975).

My close perusal of all of the volumes of evidence to that Commission has confirmed these features. I have not, however, examined the minutes of the Commission's meetings. The Commission was patently alarmed at the grandiose plans for soil conservation when the new soil conservation body gave evidence of what it had in mind. The sittings of the Commission were followed with considerable interest by the reading public both rural and urban. Much was expected of it and it could not satisfy all expectations.

The Commission was unashamedly organisationally partisan in its report. It found fault with one feature of the Department of Scientific Research publication No.92, on high country soil

erosion (Gibbs and Raeside, 1945), and accordingly rejected the publication entirely. It recommended its revision and its replacement in educational institutions. It could only describe bulletins on soil erosion which had appeared from various sources as "propaganda" and considered that "for the future no bulletins on the subject of land and agriculture should be issued under the authority of the government unless they bear the express approval of the Directors General of Lands and Agriculture to the text, and both of these officers should satisfy themselves that the statements included are facts".

Considered dispassionately, the Royal Commission's findings in this regard can only be considered as a renunciation of science. Science was to be palatable and approved by appropriate authority or it was to be rejected as "propaganda". It is ironic therefore that, having rejected Gibbs and Raeside (1945) and having ignored the "expert" Committee of Inquiry (1939) and the "lay" Commission (1940), this Royal Commission (1949) should have been so earnest in its endorsement of the Southern Pastoral Lands Commission (1920), which was, as pointed out earlier, so strong on mere opinion, and weak on fact or factually-based valid inference.

Erosion - normal or nasty?

The Royal Commission on Sheep-farming Industry (1949) was not without value. It promoted studies in farm economics and it promoted support for rabbit destruction. It brought some counteracting notes of realism into a soil erosion debate which had in some respects at least, grown to the heights of metaphor without the prospect of resolution. Thus when it came to deal with the "administration of soil conservation", it thought it "imperative that erosion should be considered in its correct perspective". To establish such a perspective, it offered two considerations. First, it proposed as uncontentious "the aim to have as much of our land as possible permanently available in such a condition that it will give the maximum production". Erosion was a problem when it left infertile land, or left a pasture subject to deterioration, not otherwise. Second, it acknowledged that the geophysical development of the land involved natural processes such as erosion which defied any human attempts to stop it. Unlike the pre-war committee of experts, it saw erosion as, in essence, uncontrollable. It was at the same time strictly utilitarian and pragmatic. Cumberland (1949) writing specially for "The Press" in Christchurch, sought to disabuse the Commission of its confusion, even if the Commission was unmindful of it:

> "The commission has made the mistake to which most people are at first prone, of failing to see the difference between 'erosion' and 'soil erosion' - between a slow, normal, geologic process and a rapidly accelerating process, caused directly or indirectly by man, whether farmer, lumberman, gold dredge operator, or careless hiker who lights a grass fire". (The Press, Christchurch, Tuesday July 12, 1949).

By the time that Molloy (1962, 1964) was beginning to clarify the role of destructive fires in Polynesian times, in initiating a new phase of slope instability in the Canterbury mountains, Cumberland (1962) was also prepared to include moahunters along with his list of careless hikers. By the time that Whitehouse (1984) reviewed in a changing perspective, the recent studies of erosion in the eastern South Island high country, many of us had begun to learn that simplistic distinctions between normal and accelerated, natural and man-made, Polynesian-made and European-made, were neither good science stories nor good utility stories. In attempting to defend science it was possible to make just as many errors as in attempting to discredit it. The real test of the worth of science would come in the application to such a landscape in becoming, of a unified theory of understanding and interpretation, such as the concept of

geomorphic thresholds of Schumm (1979), and to have such a theory stand up against our attempts to knock it down with facts. In such a way would we know where we were in our landscape processes in time and place, how an act of disturbance in one situation might be gently absorbed and apparently forgiven, how in another situation it might initiate a chain of consequences that would be in fact neither reversible nor arrestable.

The science stories of soil erosion and causes and consequences are still in the telling. The noblest irony of all affecting the Royal Commission into the Sheep-farming Industry of 1949 concerned its utility stories. The Commission asserted that "if the recommendations we have made for assistance to marginal lands, land utilization, the provision of fertilizer, the extermination of rabbits and the replacement of cover on depleted areas are all carried out, there will be no accelerated erosion on a national scale in New Zealand" (Royal Commission, 1949 p.105). As I have noted elsewhere (O'Connor, 1978a), these measures have been the successful tools of soil conservation in the high country. Soil erosion has been abated insofar as these recommendations have been applied. Soil resources have been effectively conserved by these instruments. What is especially ironic is that there was nothing in the Royal Commission's report to indicate that it ever saw "provision of fertiliser" as appropriate to the high country. Furthermore, the Catchment Boards, whose abolition it had recommended, proved to be the agencies by which technical and financial assistance was channelled into many of the high country runs, at least in the early stages of their pastoral renewal (Whitby, 1979; Harris, 1982; Kerr and Douglas, 1984).

Pastoralism or pastoral farming?

The sustained phase of pastoral degeneration had been characterised by a deviation of science stories, first from reality, and then from the myths of accepted utility stories, as some later scientists attempted to steer their stories back towards reality. For some scientists, reality proved elusive.

Similarly, reality proved elusive for the continuing utility stories of land administrators and of many of the land users. At the very time when a new interpretation of tussock country reality was taking shape in the minds of some practical people, the Land Act of 1948 set in statute the ancient and traditional mythology, that the tussock high country was not suited to farming of any kind whatsoever, but only to "pastoral purposes".

This Land Bill was introduced in 1948 as a stroke of some brilliance, apparently to forestall the wrath that was expected from the Royal Commission. Evidence had been presented to the Royal Commission of administrative failings in the Department of Lands and Survey. As McLeod (1975) has observed "it seemed obvious that the Lands and Survey Department was determined to show how ill-fitting the committee's (sic) criticisms were when they were preparing such an enlightened piece of legislation".

The Committee of Inquiry into Crown Pastoral Leases and Leases in Perpetuity (1982) was the first official body to make a serious attempt at "divining the concept of pastoral land as envisaged by the legislators in 1948". This Committee, the "Clayton Committee", expressed its view that consideration of the wording of the Act itself and of its predecessors and consideration of the current technology offered "convincing evidence that the sense in which the framers of Act understood 'pastoral purposes', as that phrase was used in S. 51 (1)(d), was the extensive pastoralism for which such land was traditionally used in a largely undeveloped state". (Committee of Inquiry, 1982, p.6).

When the Land Act of 1948 articulated a place for pastoralism in the land use

spectrum, it identified it as pastoral land, land classified as suited only to pastoral purposes, not to farming. The legislative ink was scarcely dry when R.K. Ireland at Ribbonwood Station demonstrated with aerial clover oversowing and fertiliser how inappropriate and irrelevant was the cardinal principle of land classification in the new Land Act. Not that we should think that this was the first vigorous incursion of farming into the high country, for as even Ireland (1952) himself reminded us, he "had to go against the strong opinion of the settlers in the district", when nearly 30 years before he had ploughed, netted and sown his first 25 acre paddock of new grass. By the time he turned to aerial oversowing and topdressing in the late 1940s, he already had "approximately 1500 acres in grass and clover and all the fences are rabbit netted". By the time he was invited to present to Grassland Association in 1952 the new understandings of his revolutionary science and technology, he had already aerially oversown with clover and topdressed with superphosphate first approximately 1000 acres, then a further 2000 acres of hillside between 2000 and 3000 feet above sea level.

The incursion of cultivated paddocks into high country land use had also occurred in the Waimakariri, in the Rakaia, Ashburton and Rangitata, as well as in parts of the Mackenzie, Central Otago and upland Southland and coastal Otago, decades before. What had not been noticed was that some runholders and other innovators had even spread superphosphate and clovers on tussock hillsides above such cultivated paddocks, 10 years and more before the land administration guided the legislature into the Land Act, 1948. This Act would allow and encourage the Land Settlement Board to classify such land as unsuitable for such conventions of farming. What is perhaps most worthy of our notice is that this scientific revolution to high country farming was led, not by an established scientist, whether agronomist, nutritionist, botanist or ecologist, but by an investigative farmer who presented this utility story under the heading "tussock land: marginal land" (Ireland, 1952).

The early 1950s marked a tremendous surge of experimental work into the agronomy of "tussock grassland improvement" which continued through medium of oversowing and overdrilling of legumes and grasses, with legume inoculation, sulphur, phosphorus and molybdenum fertilisers, almost without abatement until the late 1960s. The pioneer post-war work of grass cultivar evaluation by Lambert and Holmes in Southland, Hercus, Tothill and Lunn in Central Otago, Dunbar and McNeur in North Otago, Lambert and Sievwright in the Mackenzie, Sewell in North Canterbury, Wilkie, Simpson and Moore in Marlborough, is summarised by O'Connor (1980a). It was now accompanied by a tide of plant nutrient experiments in which farmers worked with agronomists and soil scientists in districts from Southland to Marlborough. Different themes were evident, e.g. the role of sulphur and molybdenum in North Otago (Lobb, 1952, 1953, 1953a; Lobb and Reynolds, 1956); the interplay of seeding method and farmer practice in the Mackenzie country and Canterbury (Sievwright, 1955, 1956, 1957; Blackmore, 1952; O'Connor, 1966a; McLeod, 1974); the relationship of phosphorus deficiency as well as sulphur deficiency to soil forming factors, especially climate and topography (Walker et al., 1955; Ludecke, 1960, 1962; Bennetts, 1957; O'Connor, 1960, 1962); the significance of cover and grazing conditions affecting fertiliser effectiveness and seedling establishment (Cullen, 1966, 1969; O'Connor, 1963, 1967).

When McCaskill (1963) came to review the recent advances in tussock grassland it was possible to touch on only a few items in each of a number of major research topics in botany, climatology, soil biology, entomology, soil physics, soil and land classification, as well as in agronomic and

management topics. The information explosion has continued in these fields as well as in hydrology, geology, geomorphology, pedology, population and systems ecology, such that now even catalogues of research activity are difficult to keep up-to-date. Fortunately the integrative wisdom of scientific story-tellers has not been totally immersed in the flood of information. What is especially significant is that science, like land uses such as farming and forestry, has brought tussock grasslands back into the mainstream of New Zealand life and thought, in ways that had never been true since the early decades of European settlement. Let us examine these translations of use and of thought.

A land use translation

Several factors have changed since 1950 affecting high country pastoral land use. New pastoral leases operated under the 1948 Land Act. They had perpetual right of renewal while remaining as leases. This improved the feeling of security. The 1951 wool boom made income available for investment. Community co-ordination under a new nationwide policy allowed effective rabbit destruction campaigns, with persistent benefits in all but the most rabbit-prone terrain. Soil and vegetation studies assisted the understanding of existing vegetation. Agronomic and soil fertility research allowed the establishment of climatically suited legumes and of grasses which were often more suited to improve fertility, more tolerant of intensified grazing management, and more useful at critical seasons in the livestock nutrition calendar. Technological developments multiplied, such as the advent of 4-wheel drive vehicles, hill track-making equipment and skills, seed pelleting, improved aerial application of seed and fertiliser materials, better fencing including the development of permanent electric fencing, development of sod-seeding equipment for rough terrain, improved stock handling facilities.

This mere listing of features of the technological revolution which was to gnaw at and eventually break through the crust of administrative and managerial resistance does not convey the extent and character of that change, either in the nature of the land use or in the attitudes of the people involved.

I have elsewhere referred to the latest major phase in the pastoral history of the tussock grasslands (O'Connor and Kerr, 1978) as a "recovery phase" or a "restoration period". Likewise in O'Connor (1978), I referred to it as a time of "ecologic and economic recovery", and in O'Connor et al. (1986) as "a stage of restoration of pastoral vitality". Each of these phrases has some merit but each fails to convey the sense of renaissance, even of metamorphosis which has occurred in the high country pastoral industry.

This is shown first in a periodically dramatic increase in livestock numbers and output. For the Central Otago runs, an appreciable increase was first demonstrated from 1951 by Warner (1956) as a consequence of rabbit destruction. O'Connor and Kerr (1978) demonstrated an approximate doubling of total stock units in the runs of the Upper Clutha in the 21 years from 1951. In the same period O'Connor (1980) showed for the same area more than eight-fold increase in cattle sales, more than five-fold increase in sheep sales, and a 70 per cent increase in total wool output.

In the first 11 years from 1966 in which the Tussock Grasslands and Mountain Lands Institute monitored the production of all high country runs in the South Island, total stock units carried increase by a crude annual rate of 3.5 per cent, cattle sales by 16 per cent per year, sheep sales by 4.6 per cent per year and total wool production by one per cent per year. (Kerr et al., 1979). Sufficient information has become available from these periodic surveys (Hughes, 1974) to indicate that these rates of increase have not been

constant but have been considerably influenced by then current economic conditions and government policies. Thus for the six years from 1966 the crude mean annual rate of increase in livestock units for all high country runs was five per cent. From 1972 to 1977 it was approximately 1.8 per cent but from 1977 to 1981/82 it increased to more than 4.2 per cent (Kerr and Lefever, 1984).

From surveys of land use and land condition carried out in various parts of the high country up to 1972, and from the TGMLI production surveys carried out since 1972 (Kerr and Lefever, 1984) the following estimates are made in Table 1 of percentage area of all runs which were in land developed or improved by sowing of pastures, lucerne or crops or by topdressing and overdrilling or oversowing grasslands.

TABLE 1: Change in proportion of high country run area which has been developed from 1952 to 1982.

1952	<1 per cent
1966	4 per cent
1972	8 per cent
1977	11 per cent
1982	17 per cent

As Kerr and Lefever (1984) have pointed out, the rate of new land development has fluctuated widely and the recent "resurgence of land development, prompted in part by recent government incentives has largely occurred south of the Waitaki River". Whereas on average, runs had doubled their area of developed land from 1972 to 1982, from 952 hectares to 1855 hectares, runholders responding to this survey visualised a potential development of some 2500 hectares with substantial further increases in livestock numbers.

These events were not all changes and development prompted by the simple interaction of oriented scientists with scientific pastoral farmers. Many of them were much more complex in their causes. Some of the changes arose from forces well-removed from the traditional or historic pastoral precedent. Some came from attitudes little affected by scientific discovery. The most noteworthy feature was the complexity of stimulus and response, cause and consequence. A string of such events illustrates.

Soil conservators promoted cattle to reduce the need for burning. The cattle obliged, often by reducing the tall tussock on shady faces where a 100 years of periodic fire and sheep had failed. Wintering cattle poached swamps. Draglines dug ditches. Wetlands were dried out. Engineers' dams drowned more wetlands, diverted some rivers, impounded others and of some retained only the channel as a coronary by-pass. Runholders and foresters built huts for mustering and for deer control. Trampers used the huts and came back with friends. Friends joined into clubs while some marketed their experience as guides to tourists. Some overfished the best water. Traditional anglers stacked hay bales when the fishing was poor. Shooters gave up on scanty deer-stalking and took up with helicopter crews in successive waves of meat recovery and deer capture for deer farming. Runholders built deer paddocks and new stock yards. Some runholders started ski-fields, deerparks, tourist lodges. Some sold up for a quieter life.

These processes of adjustment and change were carried out by a vigorous and adaptive people, both in production and recreation and in all the intergrades of work and fun between. Sadly they were not matched by vigorous and adaptive legislation and administration. Fifteen years ago (O'Connor, 1970) I expressed to the High Country Committee of Federated Farmers at Timaru my concern that refuge could be taken too easily in the rule of law: "For me the code of positive law is itself a dynamic expression of the continually evolving

cultural tradition of a people in response to changing environment and changing awareness of that environment both social and physical. I no more expect the problems of 1984 to be met by the Acts of 1948 than I expect to fly to the Chatham Islands in a horse and buggy".

Appetites for change

There is no special joy in being a dismal prophet and being right. More than a decade later, (O'Connor, 1981) I attempted to identify the main streams of change in the wildly braiding currents of resource use which now belonged to the tussock and mountain lands. There were changing ideas in recreation, changing ideas about high country farming, changing patterns of land use, changing perceptions of the possibilities for diversity in landscape, changing research approaches, changing social awareness, even changes in public administration, and above all changes in economic appetites.

I have made my own plea (O'Connor, 1982) additional to the urgent case for conservation of representative tussock grasslands and wetlands that has been articulated by Kelly (1972), Scott (1979), Allen (1976), Williams (1982), Wardle (1978), O'Connor and Molloy (1979), Mark (1982, 1985). As an agronomist and ecologist, and as a change agent in land use, I have a special interest in the managed maintenance of reference areas, benchmarks in nature and culture for the monitoring of the processes and stages of continuing change.

In the same spirit as I outlined principles and processes for reconciling and integrating different and often potentially conflicting uses (O'Connor, 1970, 1978a), so I have illustrated the main elements of potential future land use for Canterbury hill and high country (O'Connor, 1983). There is now a readiness of science and land use to relate to one another that resembles the spirit of more than a century ago. There the resemblance ends for in the luxuriance of both use opportunity and scientific understanding, the present era is in vivid contrast with the "lean pickings" of the establishment of pastoralism.

Legislative lag

"1984" has come and gone in both fact and symbol. The 1948 law has been tinkered with but never has it been subjected to a genuine creative scrutiny of lawmakers in a way that welfare of the land, the public interest, the Crown and its lessees could all be fairly taken into account (Blake et al., 1983). Now we have a nonsense where pastoral land is defined as land suitable or adaptable "primarily for pastoral purposes only" (emphasis mine!). Recreation permits and special leases have thus been issued after consideration, in response to the legitimate wishes of lessees to diversify and use the opportunities which the environment and the changing demands of people provided.

The Clayton Committee of Inquiry (1982) concluded that the provision of a separate classification for pastoral land should be discontinued and the classification itself phased out. It also concluded that the Land Settlement Board should in consultation and with all speed identify "special areas that ought to be set aside with actual reserve status", and should also designate

> "those areas of pastoral land on a generously representative, though not necessarily exhaustive basis, which in the public interest ought not to be permanently alienated by the Crown for such reasons as the Board might think fit, but primarily for recreational, ecological, conservationist or similar purposes, notwithstanding that they may possess some value as grazing land. These areas when ultimately designated should be known as multiple use land".

Such areas would be surrendered from the lease at expiry of current term.

As Kerr (1984) has summarised the Land Settlement Board's reaction to these

conclusions, the Board did not endorse the recommendations of the Clayton Committee of Inquiry but instead recommended:

> "(a) the retention of the existing form of the pastoral lease;
>
> (b) the facilitation of partial reclassification of suitable land within leases; and
>
> (c) the protection of conservation and recreational values of significance".
>
> (Kerr, 1984, p.27).

As a consequence of these recommendations, we now have the prospect of continuation of pastoral farming at the discretion of the lessee on land in law classified as not suitable for that farming purpose. If the lessee so chooses, he may seek reclassification of all or part of his leased land as farm land. If it is reclassified, the lessee may pursue freeholding by ways of deferred payment licence, but may be called on to negotiate the surrender as reserve, or the covenanting or other agreement for a "protected natural area" or the like, of some part or parts of the lease after evaluation for such conservation or other purpose of public interest. As lessee of pastoral land, the lessee retains a perpetual right of renewal. Under current policy, the initiative remains with the lessee as to whether reclassification is sought or whether a special lease or recreation permit of some kind is sought. In a peculiarly ironic twist, the pastoral leaseholder, with all the restrictive covenants to his lease, continues to enjoy exclusive possession for the exercise of this limited right to pasturage and such other benefits as his title grants. The "quiet enjoyment" of his "exclusive possession" (Kerr, 1984) appears to give the pastoral lessee, under present practised policy, some kind of pre-emptive right to the exercise of any other kind of use to which the land in the lease might be suited! Whether this is what the legislature intended, whether this is consistent with the primary goals and objectives of "High Mountain" policy (New Zealand Government, 1979), whether indeed it is what the lessees themselves want as pastoralists or pastoral farmers, or even as commercial recreation managers, tourist operators, or timber producers under conditions of their leases; these are moot questions. Of more immediate importance at the present time of financial uncertainties and of "offshore" and "inshore" interests in land hold and investment, is whether it is in the public interest that pastoral lessees or special lessees be subjected to such test.

If we believe that market alone can ensure wise land use, we should at least listen to the signals which markets are telling us. If, like the Wakefield planners, we believe that market needs legislative guidance for the purpose of ensuring longer term wise land use, that belief does not exempt us from the responsibility to listen and look for market signals, and for the "sermons in stones and books in running brooks".

What I emphasise is that positive laws are of no value in guiding the market forces affecting land use if these laws are themselves blind or deaf to changes in economic or ecologic conditions. There is nothing new in the legislative and administrative lag which characterises the present New Zealand pastoral scene. O'Connor et al. (1986) have already demonstrated how slowness of administrative and legislative response dogged each of the three main phases of our pastoral history. Nor is there anything particularly unique about this New Zealand phenomenon, for Young (1984) and McConnell (1970) have identified similar features in rangeland administration in the states of Australia and the western states of the United States of America, respectively. What is especially poignant about the New Zealand scene at present is that the progress of science has been so dramatic and fruitful that opportunities for new and varied utility stories are impressive. The close relationship of forest research and forest

administration that has characterised forestry in New Zealand has not been matched for pastoral lands or pastoral farming. As Young (1984) concluded, such a relationship is vital to responsive administration. It is vital that future organisation develop from the small beginnings in recent years towards a competent research and monitoring function, so that administrators and managers "have an understanding of the biological and physical function of the land and its management". If the farming entrepreneur can have this understanding, why not the administrators and the entrepreneurs for new uses?

Science frustrated? or used?

In the space of less than 30 years of the last century, the powerful inertia of new pastoralism launched the New Zealand economy on the undulating history which has brought us to the present. At the same time it committed the mountain grasslands to an ecologic turmoil from which they are only now beginning to emerge. It is significant that this emergence has come from about 30 years of mutual interest and co-operation between pastoral farmers and other land users and professional scientists. There is no safe harbour of stable resource use in sight. It is easy to represent the present turbulence as a contest of traditional pastoral farmers with a new green wave of heavy-booted, environmental activists, committed to their own recreation and the re-creation of nature. Nothing could be further from the truth, except perhaps to say that it is all a question of stopping erosion!

As Kerr and Lefever (1984) point out, the perception of pastoral development opportunity by pastoral users is substantial. Likewise the potential deficits of natural areas for protection and recreation are real. They have very substantial policy implications (Davison, 1986). They also have major implications for science and land practice. Whether the Protected Natural Areas Programme, subsisting up to now on inter-agency unemployment handouts, can be successful in ensuring representative protection of viable natural areas in terms of the Nature Conservation Strategy (Nature Conservation Council, 1981) is a moot point. Its failure is more likely to come from the slow perceptions, timid initiatives and weak responses of land administration, or even from laggardly and weak conservation legislation, than it is from the opposition of runholders or freeholding pastoral farmers. Far from such opposition, I find among pastoral farmers increasing interest and pride in nature protection objectives and possibilities, coupled with a healthy scepticism about the need for a new bureaucracy to ensure it.

Clearly we must recognise that nature conservation and recreation objectives are not everywhere to be served by the same reservations, just because they are so in National Parks and Scenic Reserves. Just as there are differences among high country terrains in pastoral production achievements and in the economics of such production, as shown from the recent work of Bussieres (1984), so also there are differences in the suitability of land for different kinds of recreation and for different systems of adventure tourism. What our greatest imperative must be is surely to fit these uses to the nature and culture of the New Zealand mountain landscapes. We managed almost to destroy our natural vegetation heritage by the importation of non-suited pastoral practice. We contrived to recover with some kiwi ingenuity in pastoral science and practice. Are we about to repeat the experience with tourist ventures as alien as the pastoralism that failed? We suffered in the pastoral establishment phase from inadequate understanding of, support for, and attention to the Buchanans, Garvies and Armstrongs. Will we repeat the inadequacy in recreation and tourism science, whether ecologic or economic? In 1979, Government adopted a High Mountains Policy which was the fruit of debate and discussion,

drawing on the collected science and practice experience of mountain New Zealand, and the best principles of rational use enunciated by the representatives of IUCN. If there is one lesson that our past use experience should teach us, it is the necessity to work through the implications of new policy and new market conditions, as well as the experience of nature used in different ways.

We fail miserably if we adopt the principles of new policy and fail to adjust our present practices to be in harmony with them. We fail arrogantly if we become so wedded to a new set of principles however noble, that we ignore the good in what we propose to discard or neglect. We fail poorly if we neglect the economics, not just the theory but the reality of economics. We fail most irreversibly if we neglect the ecology, the patient monitoring of impact and nature's reaction, the growth of wool or trees, of sheep or deer populations, of camping visitors or skiers, of the lifestuff of the genuine planner who is repeatedly engaged in confrontations of fact and value.

My first close association with a Hellaby fellow led me to confront a quotation from Oliver Cromwell that was nailed above his desk. It had a special irony for me since Oliver Cromwell had not endeared himself to my ancestors. I believe that it may have been said by Cromwell when confronted by an armed Cavalier in search of him. As an opening gambit for such a man of action and purpose as Cromwell, it was irony enough. It served well my first Hellaby fellow and it has also encouraged me to doubt first, then get on with it. I believe that it can well serve tussock grassland scientists, planners, users and administrators: I share it with you:

> "Brother, in the bowels of Christ Jesus, think it possible you might be mistaken".

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Think snow

I. G. Chris Kerr

Introduction

Two major snowfalls within the last 20 years caused widespread loss of stock and damage to services over a relatively large area of the occupied hill and high country of the South Island. Heavy snowfalls in other years have caused localised problems for many farmers. Major snowfalls will certainly occur again. For those who (with their livestock) are at some risk of being caught by a major snowfall it is reasonable to ask: what is the state of preparedness for the next big snow?

Being prepared for snow involves knowing how to minimise the risks and knowing what to do in the event of a major snowfall.

Loss of livestock

Loss of livestock invariably results from either stock being killed directly by heavy snow or avalanche, or indirectly by their being unable to withstand long periods when trapped by snow. Experience and a knowledge of climate contributes much to the identification of snow or avalanche prone areas and

FIGURE 1: Lucky survivors.

when these areas are likely to have a snow risk.

Most 'gorge' high country runholders are only too aware of the parts of their runs which have a high risk of snow, and conversely, those parts where snow risk is relatively low. Some hill farmers away from the high country are less aware that there is some degree of snow risk in much hill country of the South Island.

There would be little argument that sheep in good condition withstand snow better than those in an emaciated condition, as sometimes happens at the end of a hard winter (after a dry autumn) on heavily stocked properties. Similarly, if all other conditions are equal, merino and related breeds are generally regarded as better able to withstand snow than crossbred sheep. Practices such as delayed lambing, blade shearing, and the creation and use of 'winter' blocks are at least, in part, aimed at minimising snow losses.

The snow of 1895 is recorded as having caused extremely high losses of livestock. By all account the 1895 snow was truly exceptional. Even so, it is hard to conceive that the massive losses on Richmond and Mt Gerald (formerly one property) would be all that much less in 1967 or 1973 if those runs between them had been running about 20,000 sheep with virtually no winter feeding, as was reputed to be the case in 1895. Today both runs carry about 10,000 sheep and there are vastly improved subdivision, feed supplies, equipment, and access. The lesson is that the nature of the land (and to a degree the improvements) of which a run is comprised, and the condition of the stock is likely to limit what is a safe carrying capacity of that run. Clearly that lesson had not been learnt by 1895.

Action since 1967 and 1973 snows

Since the snow emergencies of 1967 and 1973, various agencies have been reviewing procedures and equipment needs. Major developments have taken place in many areas with the placing of telephone cables underground or the use of radio signals for telephone transmission. Likewise there have been several new radio telephone systems put in place - but alas, as far as is known, no district has a single emergency channel for all radio telephone systems. Minimum building standards have been incorporated into local authority by-laws to take account of possible snow loadings.

In 1984 the Ministry of Agriculture and Fisheries reviewed its emergency response procedures to cover adverse events such as flood, snow, fire, pests and disease. Action plans have been put in place. Part of these plans include the provision for farmers to act as 'wardens' of adverse events and report them to the nearest Farm Advisory Officer who will initiate whatever action is necessary.

District offices of the Ministry have distributed to farmers in snow prone areas, a useful printed card of instructions, 'what to do in a snowfall emergency'. In brief, the card says:

"IF LIFE IS IN DANGER
- contact police or Civil Defence (by telephone or radio- telephone).

- make a RED (or other coloured) CROSS in the open snow near your house.

IF LIVESTOCK IS IN DANGER
- contact Farm Advisory Officer, MAF
- make a coloured CIRCLE in the open snow near your house

GENERALLY
- clear a helicopter landing zone
- listen to local radio station for messages."

Emergency procedures

The experience of the 1967 and 1973 snowfalls is well recorded (Hughes, 1967

and 1974) and several recommendations were made for improving the effectiveness of emergency operations. In summary these are:

1. General

(i) Emergency services may need to be provided by N.Z. Police, Civil Defence, county councils, power boards, Ministry of Agriculture and Fisheries, catchment authorities, Ministry of Works and Development, Ministry of Energy, Ministry of Transport, N.Z. Post Office, N.Z. Army, Royal N.Z. Air Force, Federated Farmers of N.Z. (Inc.), and voluntary organisations. (Immediately after a heavy snowfall, a meeting of emergency controllers from the participating organisations is essential to integrate activities.)

(ii) A central emergency headquarters (e.g. Police Operations Room) should be established (to maintain co-ordination of emergency services, decide human welfare issues, and use broadcast radio to relay information at regular times to people without access or telephone, or in stranded vehicles).

(iii) Good communication systems are essential (underground telephone cables; call in Army Signals unit - which is self-contained, expert, and experienced; one emergency channel for all radio telephone systems; distribute portable radio-telephone sets).

2. Livestock

(i) Farmers in snow prone areas:

- have own, or ready access to, snow clearing equipment (and begin snow clearing immediately),
- maintain adequate feed reserves (hay, sheep nuts etc.),
- keep necessary veterinary supplies (propylene glycol, penicillin, calcium borogluconate).

(ii) Agencies (especially MAF) in snow prone areas:

- make early reconnaissance (be familiar with civil or military fixed wing or helicopter operating procedures),
- have a plan of operation for use in emergencies and maintain good records of messages, schedules, action taken etc. (MAF farm advisory officers usually co-ordinate livestock rescue.),
- have, or have access to, radio-telephone equipment able to cover district from base and four-wheeled drive vehicle(s).

3. Access

(i) Begin snow clearing operations as soon as snow begins to lie (work in teams, keep going during daylight hours).

(ii) Snow clearing teams must report regularly to base on progress and on conditions (this information must be passed on to emergency headquarters).

(iii) All rubber-tyred machines and vehicles need chains in snow.

(iv) Control sightseers.

Conclusion

One of the most telling comments to emerge from the recent heavy snowfalls was the failure of some agencies to:

(a) tell others what they are doing,
(b) learn from the experience of earlier snowfalls.

Being prepared is knowing what to do.

It is time to THINK SNOW

Copies of 'The Snow of August 1973', by J.G. Hughes (Special Publication No.10), are available from the Centre for Resource Management, P O Box 56, Lincoln College, price $6.

The Algidus wool wagon

Jim Morris

The wool wagon stood by the stable
A relic of former days,
Slightly battered and twisted
Etched in the sunset's rays.
And as I smoked in the evening
A final pipe before bed,
I fancy I heard the tall wheels creak
And old sounds came to my head.

.....

The snorts of the team at daybreak
As into their stalls they came,
Keen for a feed of hay and chaff
And a pannikin of grain.

The stamp of feet as the collars
and hames are buckled tight,
With the back pad and the britchen
In the early morning light.

The "Whoas", "Come heres" and "Gee backs"
As the shafters were backed in square,
The jingle of the trace chains,
And I wished that I was there.

The swingle trees a clanking
And the leaders are hooked up too,
The brake off, and a loud, "Get up",
And the start of a job to do.

For the shearing's nearly over
There's wool a plenty to cart,
And the shoes clink on the roadway
As we back up to make a start.

The thud of bales as we load them
In the wagon bed there's four
A dozen roped above this base
The river's too high for more.

The clunk of wheels on the boulders,
The roar of the water swift,
An anxious neigh from the youngster
As she feels the wagon shift.

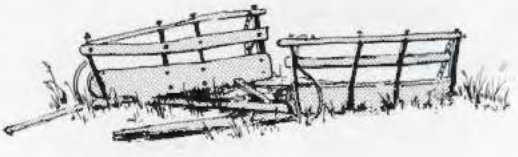
But we're out, with the water streaming
Off, from the backs of the team,
And the river takes on a lighter note
As through the worst we've been.

The "Iron Stores" behind us
Where we offload the bales of wool,
Homeward bound for another load
The horses are keen to pull.

They're playing with the snaffles
Almost dancing on their feet,
The feel on the lines of horses eight
Is something that can't be beat.

.....

At length the darkness roused me
And I wandered away to rest,
And thought of the noisy diesels;
Is this what they call progress?



Roles for forestry in high country land use

K. F. O'Connor

Purpose and perspective

The purpose of this paper is to give a progress report on some recent and current research and to offer a prospectus for the future. The research in part was carried out at Forest Research Institute, NZFS, at Ilam; in part it has been conducted as Masters theses by students under my supervision at the Centre for Resource Management and with the cooperation of New Zealand Forest Service, Department of Lands and Survey, and hill and high country farmers, especially in central Canterbury; in part it has been an exercise in collating technical information, especially on soil chemistry and fertility, from a wide range of sources. This last has been done with active collaboration from officers of New Zealand Forest Service; Ministry of Agriculture and Fisheries, especially at Invermay and Tara Hills; Soil Bureau of DSIR, at Lincoln and Lower Hutt; several departments of Lincoln College and University of Canterbury, including colleagues in the Centre for Resource Management. Apart from some of the already published research referred to from Forest Research Institute at Ilam, none of the projects involved has yet been formally submitted for publication. This progress report does no more than touch on salient features which will be presented in the context of fuller reports elsewhere.

This progress report is presented as the basis for a summary prospectus for further collaborative research. This prospectus is published in summary form at the present time so that interested parties, including high country farmers, visitors and administrators, can share a common understanding of some new approaches in land use research. The sponsorship and funding of most of this future research has still to be arranged. It is part of my approach to such collaborative research that the basis for sharing in work and costs should be openly negotiated.

Forests, past and present

High country forests are the predecessors of much of the high country grasslands. We are indebted to Molloy et al. (1963) for our general understanding of the role of fire, especially in early Polynesian times, in the destruction of podocarp and beech forest. In an essay in this issue of Review (O'Connor, 1986) I indicate how early botanical explorers such as Buchanan and Travers were aware of the recent and often current forest destruction that extended these earlier induced native grasslands. Botanists such as Wells (1972) have described forest remnants such as the thin-barked totara forests of Central Otago. Apart from the remnants in National Parks e.g. Mt Aspiring (Mark, 1977), we have little account of the extensive valley floor forests in which matai was often the principal milled timber. Most such forest was cleared by fire. Morris (1978) has noted that "timber quality of the mountain forests was generally poor with the exception of occasional stands on fertile valley floors". For this reason as well as remoteness, the only consumptive use of mountain forests by early settlers was of local stands for firewood, some fencing and building. How widespread in Central and eastern

Otago and in Canterbury were the kowhai forests of which some small remnants remain in hillside as well as riparian situations, we do not know. Remnants of scrub forests of such species as bog pine, celery pine, ribbonwood, kanuka and manuka occur in many parts of the high country, many of them the subject of nature conservation proposals in recent years. Roche (1984) has given a useful summary account of sources for such forest history.

Present forest distribution in the high country is therefore residual so far as the indigenous elements are concerned. The slow marginal extension of beech forests is a feature of the "interior" high country in the humid zone of "gorge runs" and of the "lakes runs" of Otago and Southland. Kerr and Lefever (1984) reported an average of just over 100 hectares of forest, indigenous and plantation, per high country run. It is interpreted that this average figure excludes the areas of State Forest that may occur as remnant outliers within the pastoral zone but not included in the pastoral lease. Kerr et al. (1979) had reported a total area of 4247 hectares of new and existing exotic plantations on 218 runs in 1977/78.

The exotic plantation forests on high country runs are described for Canterbury from a recent survey by Ledgard and Belton (1985, 1985a). Data from Kerr et al. (1979) indicate that the area per run (14 ha) in Canterbury was then intermediate between Marlborough (100 ha) and Otago/Southland (4 ha).

Many of these plantation areas have been in the past established as a requirement of the lease. The larger areas result from the enthusiasm of particular individuals like H.E. Hart of Lake Coleridge Power Station, T.D. Burnett of Mt Cook Station and Mackenzie County Council, composer of the famed message in stone on the Burkes Pass monument.

Afforestation in greater or less degree has been promoted in the high country since Morrison (1919) and the plantings at the same time in Cockayne's revegetation experiments on the Northburn run in Central Otago (Douglas, 1970). Afforestation received a stimulus for revegetation especially of eroding sites (Wendelken, 1956; New Zealand Forest Service, 1967; Orwin, 1978). The dramatic productivity of such mountain forestry has received international attention in recent years (Benecke and Davis, (eds) 1980). The prospects for uses of production forestry in the high country have been outlined by Nordmeyer (1979) and by Ledgard and Baker (1982) as well as by Ledgard and Belton (1985, 1985a).

As well as the planted forests there are the beginnings of extensive forests in the high country as the consequence of voluntary spread of seedlings from existing plantations (Hunter and Douglas, 1984). This prospect is perhaps nowhere more dramatic than in the progressive increase in establishment of Pinus nigra, P. ponderosa and P. radiata in several of the Cockayne plots on the Northburn run. What was for several years represented as a peculiar problem of Pinus contorta is now increasingly recognised as an ecological manifestation of success in revegetation. It demonstrates that most of the tussock grassland area below the upper subalpine zone is endowed with a climate suited to forest growth. It is this last climatic feature which is central to the development in the high country over the last 30 years of high producing pastures, with essentially the same plant materials, principles and practices as have been applied elsewhere in New Zealand. It is this same feature which demands that we examine possible roles for forestry in the high country in the future.

Attitudes to forestry

Attitudes and opinions concerning forestry in high country landscapes would seem to be perhaps as varied as the landscapes themselves. Opinions range from strong aversion to the

presence of alien conifers in what is thought to be a natural tussock grassland to a strong preference for grand scale tree planting as a positive forestry land use. In between may be found many landscape designers who see the possibility of "creative forestry" as a way of enhancing quality and diversity. Clearly there are no universally valid prescriptions and where and how trees are planted and managed may be much more important than whether or not to tolerate them at all. Professional training in land use planning, ecology or landscape architecture does not of itself ensure aesthetic taste and wisdom. Discernment of quality can be elusive for the professional as well as for the layperson.

We have little information about the attitudes of visitors to the high country about tree planting. A small and unpublished survey of winter visitors to the Mackenzie was done by a post-graduate student Pauline Gibbons (Cant and O'Connor, 1977). While openness and grand scale were frequently identified as attractive features of that basin, apparent barrenness was sometimes counted as unattractive. Most visitors however considered that irrigated land development and tree planting would enhance the scene. This question of land perception and discernment and valuing of "quality" warrants careful research.

During last year a more detailed study was made of the attitudes and opinions concerning exotic forests of 25 high country pastoral farmers from the Rakaia to the Ashley (Murray, 1986). There were marked differences between localities within the study area in present length of shelterbelts and area of woodlots. There were also differences, but not truly parallel with existing practice, in long term aspirations. Overall, more than half the farmers had a long term aspiration for a significant level of commercial forestry, combined with shelter forestry. All wanted at least shelter forestry. Most were maintaining or increasing their rate of planting. Reduction in rate of planting seemed to be associated with experience of planting failure. All 25 interviewed said that some sort of tree planting would improve the high country as a place to farm and live. More than 80 per cent indicated that only forestry that was complementary to sheep and cattle farming was acceptable.

Visual landscape quality was most often identified with openness, majesty, and especially diversity in season and terrain. More than 90 per cent thought that large-scale forestry would detract from the landscape quality. More than 70 per cent thought that carefully planned woodlots and shelterbelts in some situation or other would enhance the landscape. However, a third of the total indicated that such planting ought to be confined to the flats and excluded from the hills.

Seventy-six per cent of farmers interviewed agreed that wildlings were a cause for concern and most of these considered that this problem affected where on the ground and in what conditions of vegetation should planting be done. Some saw wildling spread as a potential "neighbour problem". A small minority saw wildling spread on to "Class VII and VIII land" as acceptable or even enhancing otherwise poorly productive land. The threat to "natural areas" was not particularly well recognised.

Three-quarters of all farmers were in favour of some form of control of planting, generally at district level, rather than leaving it uncontrolled. All looked with favour on joint ventures for investment in forestry. The single biggest factor apparently affecting decision making in favour of forestry development was the farmer's own stage of farm development. Shelter planting was apparently given earlier attention in property development. Woodlot planting tended to be regarded as more fitted to a later development stage when money for investment became

available. "Older fathers may plant so that later heirs might harvest."

Farm forestry options

The above summary which I have made of some salient features of Murray's (1986) intensive survey confirms for an admittedly small but concentrated sample what many have come to recognise: that most high country farmers and their families value their environment in a caring, sensible and neighbourly way. Their caution about embarking on forestry on a large scale is affected by such environmental stewardship concerns as well as by many economic considerations. One can understand that a farmer's view of what is desirable in a loved environment is more affected by what is familiar than by what is ecologically original or primitive. Landscape assessors may behave similarly but with less justification. Farmers displayed a strong disposition in favour of the kind of forestry development that was in harmony with the particular economic and ecologic realities with which they were principally concerned, i.e. pastoral farming. Provision of stock shelter, provision of visual amenity, utilisation of pastorally unsuited ground, provision of alternative opportunity for investment and of supplementary income at some time in the future - all of these considerations were generally important. Each of these is consistent with a genuine pastoral farming attitude. They may seem to be simply common sense but because they are frequently doubted or contested we should be grateful to Murray (1986) for establishing them so clearly.

He also found that runholders were often well-informed about forest planting technology, that they knew where to go for advice and service in such matters and that their spouses were often as interested in these affairs as they were, especially about the maintenance and enhancement of the familiar and authentic visual landscape. In short, farmers and families were clearly interested in farm forestry. The form or forms in which they were going to develop it, their pace of progress and the economic, ecologic and aesthetic success of such ventures were all, in some way, problematical but not approached without skill or confidence.

There are various ways of integrating agriculture in various forms with forestry. Nordmeyer (1979) introduced three main functions for forestry as a land use option with high country pastoral farming. He identified these as shelter, production and land protection. Within the production role he gave special attention to the potential for producing an energy feedstock. This option continues to be examined in different studies, including some involving this Centre. Ledgard and Baker (1982) and Ledgard and Belton (1985a) have both developed our understanding of the range of options for use of forests in high country. The shelter option was examined by Nordmeyer (1979), for example, in terms of timber and shelter especially to legumes from wide shelter belts, and from a mutual shelter and fire break system in a mosaic of tree plantations and pasture in something approaching a 40/60 system. Ledgard and Belton (1985a) point out how farm forestry would have most compatibility with existing conditions of use and tenure in the high country.

At this stage I should confess that personally I had different influences at work on my mind and body promoting the use of forest trees, especially for shelter. Most of them were in actual physical experience but some of them were in the word of mouth of memorable people and unforgettable moments. From as wide a range as Buchanan (1880) to Garden (1983) I had influences coming from people who lamented the lack of shelter for livestock, something "more than a wire fence". I had done as much research as anybody else on the grazing manipulation of tussock grassland pastures to maintain the tussock while utilising the feed resource. I knew that it was possible but difficult

(O'Connor, 1966). From people as experienced in different ways as Jack Cameron at Ben Ohau and F.R. Callaghan, formerly Secretary of DSIR and later scientific advisor to the New Zealand Wool Board, I had a continual pricking to investigate and understand the role of "inforest " shelter. From my field experience in as widely different environments as the often close-forested oak and conifer stands of the Himalaya and Siwaliks in Northern India and the open forest range of Ponderosa and Juniper and the like in the mountain and western states of the United States of America, I had a constant recollection of contented mobs of grazing sheep in a two-storeyed vegetation system.

I suspected that how trees were to be marketed would greatly affect how they should be grown, species-wise, tending-wise, spacing-wise and location-wise e.g. Groome (1983), Donald (1983). But I also know enough of the influence of future uncertainty in decision making, especially at long horizons, to know that present conditions had to have a major influence on decisions and future products should already be harbingers of options themselves; they should have versatility.

There are various ways of integrating agriculture with forestry. I had seen some in India and the United States. I had worked in Southern Chile and I knew that it was the only place on God's earth that was windier than New Zealand. I had seen ground crops grown on the floor of dense rubber plantations in Malaya. I had seen them eaten by managed livestock, including birds, and I had seen them used simply as green manure. I had suspected that the light conditions of the tropics allowed this luxuriance.

I had read in my history books of the rights of pannage in the oak forests of Europe. I read from Glacken's "Traces on the Rhodian Shore" that much of the forest conservation of western Europe was achieved by one law or edict or the like that preserved the game rights for the local dignitary and left to the middle-incomed and the poor the rights to the faggots and the bundles of twigs. I had stopped by the roadside near Abruzzi National Park in Italy and in broken Italian found that this partition of rights was in functional order. Likewise, I had found that the Lombardy and other poplars for which northern Italy was famed raised the "roughness height of vegetation" to allow the full productivity of a rich Paduan agriculture to be protected from the transalpine winds. It was not too surprising to find (Callaghan et al., 1986) that Bryant and Mays have been practising silvoarable as well as silvopastoral cultures on their Hereford estates.

I can conceive the high density shelter systems of kiwifruit orchards as one end of a New Zealand farm forestry spectrum (Sturrock, 1984a). In New Zealand both foresters and farmers have been interested in farm forestry, but for some time they approached it from quite different standpoints. The origins of these different standpoints lie in New Zealand's strong cultural separation of farming from forestry. This seems to have been inherited from Britain at least from the time of the enclosures, in part it has been developed from New Zealand's ecologic experience. (As Caughley (1983) remarks, there have been some super-sensitive botanists in New Zealand, including Leonard Cockayne, who seemed to believe that no animals that browsed or grazed had any place in a New Zealand native forest.) These ideological and historical influences have been reinforced by bureaucratic separation that was founded more than 70 years ago. (Common sense has just been beginning to prevail over some of the more serious effects of this separation when it is again threatened anew under the form of separate corporatisation. In these days of mergers and takeovers, there are apparently still some idealists who believe that bureaucracy exists only in State departments and will not flourish in just about any organisation large

enough to have a division of responsiblility and needing to hire more than one secretary!) These reflections on the nature of human behaviour in large organisations aside, in New Zealand native forest grazing has been practised with and without licences for some 80 years and without the need of licences for some time before that. It has been good for the cattle and more recently the deer, but it has not been the best for the forest floor or for ground storey vegetation, including regeneration of canopy species, as the condition of many of our Scenic Reserves has testified. Licensed grazing of exotic forests has steadily increased over the years, especially for wintering.

Like the central Canterbury high country farmers surveyed by Murray (1986) many farmers have begun from and concentrated on shelter belt development and management so that they could derive wood products (Chavasse, 1984) additional to the shelter benefits appropriate to their type of farming (Sturrock, 1984; Radcliffe, 1984; Holmes and Sykes, 1984). At the other end of the cultural spectrum, foresters initially approached what evolved into integrated agro-forestry as a way of having animals do the work of "releasing", of reducing ground fire risk. From such beginnings, foresters have had increasing research and experience in forest grazing (e.g. Knowles, 1972, 1975; Tustin and Knowles, 1975; Tustin et al., 1979; Percival and Knowles, 1983; Knowles and West, 1984; Percival and Hawkes, 1985).

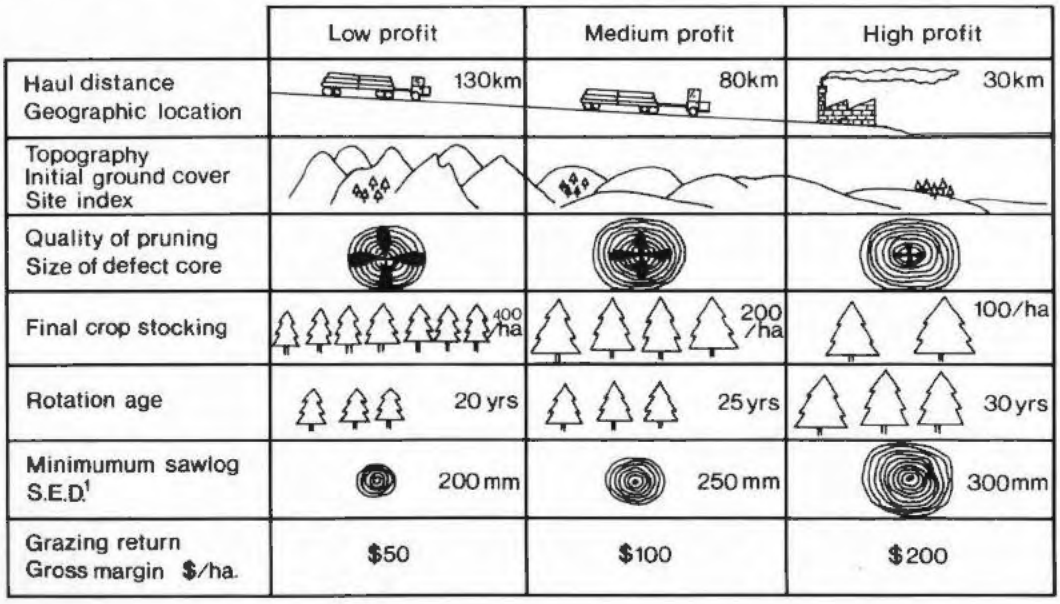
The integrated agro-forestry option

Cooperation between foresters, agricultural scientists and investigating farmers has encouraged greater fusion of purpose to have joint products, rather than what Behan (1967) once called the "succotash syndrome" of multiple use. The outcomes from these studies of integrated agro-forestry like the studies of farm forestry in a broader sense were many and varied. They showed some benefits and some losses to both livestock and forest. So also did early experience in the United Kingdom (Adams, 1975, 1976). In economic terms Arthur-Worsop (1984) and Percival and Knowles (1983) have found integrative or partly integrated agro-forestry attractive as an investment alternative to pastoral farming for North Island hill country, especially perhaps for larger properties. There are several different factors which can greatly affect profitability of agroforestry. Some of the more important of these are indicated from Figure 1, prepared from Edmonds' (1985) presentation at Invermay.

To understand why agroforestry has come upon us we have to interpret what has happened to divided or specialised land use. What has happened in New Zealand land use is that the conventional and separate development and technical improvement of production forestry and productive pastoral farming have brought each to a condition of marginality in the face of a cruel world set of market teeth. Each kind of enterprise has had "to run harder to stay in the same place". In many respects each has been extraordinarily efficient but the protected and subsidy reinforced dentures of external markets and competitors in those markets have been prepared to chomp us up as so much spare-ribs or bark waste. Farmers on hard hill country in North Island and in northern South Island have been especially hard-pressed. So too has been the low-grade production forestry, as indicated by the now well recognised findings that traditional afforestation was economically marginal and by the less well comprehended observation that in planting up such marginal country, afforesting entrepreneurs may have already received their rewards. What thorough analysis has revealed is that economic prospects for forestry could be improved "by adopting management regimes with low tree stocking rates which increase the proportion of high quality solid wood and sustain grazing and farm income through the tree growing cycle" (McDermott Associates, 1984).

It was growth to this kind of awareness that led Department of Lands and Survey and New Zealand Forest Service who had convened during 1973 "a land use committee" for Okuku Pass station in North Canterbury which the Government had just purchased that year, to collaborate in agroforestry research. This was a potential conflict zone between traditional competitors farming and forestry. Instead of resolving the issue in traditional land allocation fashion, the land was empirically classified and intuitively assessed for different functions and then allocated as different parcels, according to estimated potential use for pure farming (20 per cent), pure forestry (45 per cent), reservation of native scrub and bush (eight per cent), and integrated agroforestry. This decision has been fairly closely adhered to and a joint programme and timetable planned and followed by the two agencies. The uncultivable farm land and agroforestry land has been aerially oversown and topdressed and open forest planting in stages begun on the latter. The cultivable land has been sown in improved pastures, fertilised and limed. The forestry area has been planted mainly with radiata pine, but also with smaller areas at higher altitudes of Douglas fir on the moist shady slopes and Bishop's pine on the sunny northern faces. The forestry regime has now been adapted to aim at a final stocking of 200 stems per hectare on the pure forestry zone. A mixture of stands at 100, 150 and 200 stems per hectare are being progressively planted on the integrated agroforestry area to provide for continuing pasture support for the flock.

Into this scene, "goal programming" has been introduced by Percival (1986) to determine whether it could demonstrate any advantages over the intuitive approach to land allocation for land use decision making. GOAL - multiple objective programming (Bartlett et al., 1976) had been introduced to us by Professor Don Jameson of Colorado State University. It is now one of



[1]S.E.D. - small end diameter.

FIGURE 1: Principal factors affecting profitability in New Zealand agroforestry systems (after Edmonds, 1985).

many widely used goal programming techniques which are employed to assist decision making in the western range states, at the regional, district and individual property level. How good such a programme is depends on the quality of input information and how well it copes, if at all, with risk and uncertainty. The quality of input data governed the selection of the matrix data. The goal programming was versatile in that it could be readily adapted to new technical or economic information. Above all it showed its advantage over the intuitive approach in that it could cope with an integrative consideration of all terrain types identified for consideration in the Okuku block. In practical terms it was interesting that for all except one terrain type, integrated agroforestry would give superior goal achievement as net present value than any other use regime. Only on the best land was an option in Angora goats superior. Of the options examined, 150 stems per hectare in agroforestry was the most profitable but this tree density was still expensive, showing negative returns in most years and only in Year 30 did a substantial benefit accrue. Lower tree densities of 50 stems per hectare gave a better cash flow through sustaining animal production but they gave less overall returns (Percival, 1986).

Forest influence on fertility

In all of this work that vital ingredient of pastoral farming, fertiliser requirement, was related to livestock carrying capacity during the rotation. Some argued that we should increase the fertiliser requirement because of the "adverse" effect of pine trees. Nordmeyer (1979) had indicated that in a station of conifers with pastures, conifers could return a high proportion of phosphorus in available form and could counteract the aluminium problem which aggravates phosphorus deficiency for many of our pasture legumes.

Ledgard and Belton (1985) have just reported a survey of tree growth in high country plantations in which tree growth appears to have been principally controlled by precipitation. They looked at soil phosphorus values in 0-15 mm mineral topsoils (0.5 M H_2SO_4-soluble P) to determine whether this factor explained any of the variation in tree growth. In fact they found no such explanation but they did find that phosphorus values were high by Soil Bureau standards.

Current work in which Bruce Robson (Computer Centre) and I are collaborating with Marc Belton reveals that in comparison with samples from similar horizons in the same soil sets taken from under grassland the forest mineral topsoils appear to have been greatly enriched with phosphorus. This is illustrated in Table 1. It should be explained that these results are of a progress character only. Few of them are of closely comparable sites and there is a big range in mean values for any soil set. What seems evident however, is that over a fairly wide range of terrace fan and downland terrains in the South Island high country, a single long rotation of exotic conifer forest has not worsened the soil phosphorus situation in the pasture feeding zone but in fact seems to have bettered it.

Prospectus

We have to examine this phenomenon more carefully in strict locational comparisons. We have to cooperate with foresters and soil scientists in understanding the soil and nutrient cycling phenomena and processes which belong to this situation. We have already begun to reinterpret our animal behaviour experience in terms of nutrient returns and site selection for grazing in terms of herbage chemistry and we wish to extend this approach to understanding animal behaviour and its nutrient cycling and distribution effects in forested landscape. We know that the range of scientific and technical work and experimental comparison in this work is immense and varied. We are aware that work has already begun at our counterpart institution in the United Kingdom (Maxwell, 1986) designed to model these processes

biologically and physically as well as economically and we recognise the need to master this phase of work here, especially as a guide to the phases of experimental work and monitoring which should be given priority. Above all we see that this prospect, by its emphasis on pastoral farming cash flow as a palliative for the long delay in forestry returns, can liberate forestry from its pursuit of short rotation tree crops and give to its creative power a new restorative role in landscapes chosen for the purpose (O'Connor, 1981, 1983). We are confident that creative forestry has a genuine future in economic, aesthetic and responsible cultural landscape and we invite the interest and participation of those who share such views with us. We also recognise, as I have pointed out before (O'Connor, 1983), that nature conservation of tussock in potentially forested country, demands improved pasture management as buffer zones to control wildling spread. We recognise that there is need for practical and ecologically-informed landscape architects and planners to participate at an early stage and we recognise, as high country farmers in Central Canterbury and elsewhere do, that local control is essential for the effective application of nationally-agreed principles. New Zealand's high country landscape future is beginning in a new wave of comprehending and responsible "landship". If disused pine or oak forests give way to beech in a thousand years, it will be some thousand years before beech would arrive on its own.

TABLE 1: 0.5 h Olsen P values for soil sets under different levels of grassland development and under exotic conifers.

Soil set (Zonal soils)	Unimproved grassland	Semi-improved grassland	Improved pasture	Exotic conifer forest
B.G.E.				
Grampians	22.3	27.5	29.7	54.0
Y.G.E.				
Meyer	15.2	14.5		55.0
dry hygrous H.C.Y.B.E.				
Mackenzie	16.1	14.4	14.9	49.4
Dalgety	15.2	10.0	13.4	50.3
Pukaki	11.5	15.0	18.8	33.5
Tekapo	5.5	11.2	11.0	22.3
Ohau	5.2	7.0		23.0
hygrous H.C.Y.B.E.				
Craigieburn	10.7	11.1	14.4	18.3
Cass	13.7	17.6	10.8	31.4

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Rabbit control

I. G. Chris Kerr

Introduction

The European rabbit Oryctolagus cuniculus was introduced into New Zealand more than 100 years ago and found a favourable natural habitat in areas of Central Otago, the Upper Waitaki and inland Marlborough where the climate is mediterranean. Although they occupy much of New Zealand the density of rabbits is related to the nature of the habitat. The 'rabbit problem' is concentrated on about 100,000 hectares of extremely rabbit prone land in the South Island, mostly in Central Otago.

Rabbits reached plague proportion by the 1890s and continued to seriously affect agricultural production and nature conservation until the 1950s. The effect was widespread depletion of vegetation and accelerated soil erosion through the combined effect of burning and grazing by sheep and rabbits.

Early control methods relied on capture (mainly by trapping), poisoning, and fencing. Early legislation to establish rabbit boards to oversee rabbit control was largely ineffective. The export of rabbit skins was a substantial industry. With the inducement of a government subsidy on rates, and eventually with authority to control rabbits on private lands, rabbit boards were established. It was not until the Rabbit Nuisance Amendment Act 1947 that a 'killer' (extermination) policy was adopted and rabbits were decommercialised. The era also saw the introduction of 1080 (sodium monofluroacetate) and the aerial application of 1080-impregnated bait (mainly carrots). Vastly improved economic conditions enabled resources to be directed towards rabbit control and to pasture improvement. By the mid 1960s rabbits were under control in many areas.

The pest control industry in the mid 1960s consisted of some 210 rabbit boards covering 15 million hectares, and a Rabbit Destruction Council having overall jurisdiction. The Agricultural Pest Destruction Act 1967 widened the scope of rabbit boards (now called pest destruction boards) and an expanded Agricultural Pest Destruction Council (including representatives of Counties Association, Federated Farmers, New Zealand Forest Service and the Department of Lands and Survey). Eventually in 1971 an eradication policy was replaced by a control policy. Amalgamations resulted in a 50% reduction in the numbers of autonomous and county boards to 96. The 1:1 subsidy from government was replaced in 1981 by a system of public funding somewhat more related to need.

In recent years, agricultural pest control organisations have been subject to reviews, decisions and circumstances which have resulted in:

(a) a government intention to reduce funding and the spread of responsibility for pest control;
(b) widespread concern within the pest destruction organisation about their ability to maintain adequate control of rabbits;
(c) a review by many pest destruction boards of their rating classification;

(d) strong support from seriously affected boards and farmers for the introduction of myxomatosis.

It is the apparent intention of government to reduce pest destruction funding from $7m in 1984/85 to $3.2m by 1989/90. The result will be at least a 50% reduction in funding for most pest destruction boards. It is the further stated intention of government to discontinue funding of pest destruction by 1993/94.

It is now a requirement of government that:

(a) there should be a 50% reduction in the number of pest destruction boards;
(b) landowners pay for pest control according to the benefits of control.

Control of rabbits on highly rabbit prone land appears to be proving less successful. Both the methods of control and the management of operations by boards has been questioned. Some boards appear to be more successful than others.

One effect of reduced funding (and escalation in control costs) has been the review of rating classifications by many boards to reflect a 'user pays' system. Research into the classification of land according to rabbit proneness is proceeding.

Much of the highly rabbit prone land in Central Otago, the upper Waitaki and Marlborough is not sufficiently productive to meet the full cost of rabbit control. Few areas of this highly rabbit prone land have been successfully developed for intensive dryland farming. With a rating classification which reflects the cost of rabbit control, and without government funding of part of the control costs, land occupiers, when faced with the total cost of control, may wish to discontinue farming (invariably extensive pastoralism) and abandon the rabbit prone land unless more economic use can be made of the land. By default, the relevant Crown land administering agency or soil and water conservation authority may be required to manage the land. Any prospective alternative use for the land requires urgent examination.

The apparently increasing frequency of failure in some localities of aerial poison operations is of major concern. 'Bait shyness', management, weather, and low toxin levels have all been cited as the cause of failure. Control failures inevitably result in high costs of control as repeated attempts are made to achieve success.

A recently published environmental impact report on a proposal to introduce myxomatosis as another means of rabbit control concluded that myxomatosis would not provide a long term solution to rabbit control, and its success in the short term was not guaranteed. For these and for reasons of uncertainty and the recognition of the public opposition to myxomatosis the authors of the report did not support its introduction. The Agricultural Pest Destruction Council is seeking further advice on the matter so that it may review its position.

Throughout New Zealand several pest destruction boards have adopted 'no control' policies for all or part of their district. The success of such a policy is dependent on intensive farming in moist or humid environments where rabbit populations are naturally controlled by the unfavourable habitat, with its high incidence of disease and of predators. Unfortunately the arid areas of Central Otago, the upper Waitaki and Marlborough do not enable similar policies to be used to control rabbits to acceptably low population levels.

The use of rabbit prone land for commercial rabbit meat and skin production does not seem at all practicable because of the difficulty of containment (by fencing) and the serious depletion of vegetation and erosion of

FIGURE 1: Highly rabbit prone land in Central Otago.

soils which would result (if past experience is a guide).

The primary responsibility of pest destruction boards is to control animal pests that are affecting or threatening agricultural production. In the extremely rabbit prone land agricultural production is somewhat less of a consideration than that of the protection of the land for long-term use. The public agencies with responsibilities in land use are: catchment authorities (for soil conservation in its widest sense); Department of Lands and Survey (for Crown land); and county councils (for district planning). As the question of rabbit control on rabbit prone land is one of land use at least as much as agricultural production, it is clear that an assertive, integrated and co-operative effort by all the relevant public agencies is warranted. There is comparatively little evidence of this so far.

The Committee of the Tussock Grasslands and Mountain Lands Institute (TGMLI), in their review of the 'rabbit problem', considered among others, the following questions.

1. What is the objective of government funding of agricultural pest destruction? What is an equitable level of funding (if any)? What is an appropriate criterion for the support of control operations?

2. Is government funding a recognition of the national importance of rabbit (and oppossum etc) control? Is it a farm input subsidy? Are there overriding land use and protection considerations? Is there a case for reform of rabbit control administration to reflect these considerations?

These concerns prompted the Committee of TGMLI to write (in March 1986) to the Minister of Lands, Hon. Koro Wetere. The following letter documents the Committee's submission and recommendations.

"Hon. Koro Wetere,
Minister of Lands,
Parliament Buildings,
WELLINGTON.

Rabbit control in New Zealand

For some years the Committee of Management of T.G.M.L.I. has discussed rabbit control particularly in the hill and high country of the South Island. It has held discussions with many people involved, including scientists, runholders, land management agencies, Pest Board supervisors and operators. The Committee has twice visited rabbit prone areas in Central Otago, and recently convened a public forum in Cromwell to discuss the issues involved.

The Committee has asked me to place before you its conclusions which are summarised as follows.

The Committee believes there is an urgent need to:

1) re-define the rabbit problem;
2) review the economics of pest management;
3) review the institutional arrangements for pest management.

A RE-DEFINITION OF THE PROBLEM

Since their introduction to mainland New Zealand in the 1850s rabbits colonised most parts of the country. As new land was cleared for agricultural production rabbits found a niche free of most predators and disease.

With development and pasture improvement and control measures over the past 30 years rabbits are now of concern on a relatively small land area, where the habitat is similar to that upon which they evolved in the Iberian Peninsula.

Management vs Control

The existing pest board structure was designed to handle the large rabbit populations of the 1940s. The "killer policy" resulted in the establishment of boards throughout New Zealand, total coverage by autonomous boards being completed by 1967.

The concept of total rabbit control (extermination) meant that not only were boards established in areas where rabbits were not a problem, but board members had a commitment to eradication - a view which is firmly entrenched in many boards to this day. The problem is that reputable ecologists, such as Howard and Gibb, had for many years pointed out that total control was not practicable nor justified.

Identifying rabbit prone land

Since the mid 1960s several workers have stressed the need to grade land according to its "rabbit proneness". The 1979 gradings system based on NWASCO land inventory information, envisaged the identification within a district of the major soil types representing different degrees of rabbit proneness.

In 1983-1984 more detailed work in Central Otago confirmed the relationship between soil and vegetation type and rabbit populations. Rabbits are seldom a problem on intensively farmed land, high altitude land, or forests. They are a problem on some dry land of low carrying capacity.

The Committee is firmly of the view that funds for pest management should be targeted to areas and funds allocated accordingly. In this respect the recent decision of the Western Pest Destruction Board to opt for new approaches to management based on zoning according to rabbit proneness shows prospects for the future adoption of more cost effective methods of rabbit management.

In addition, the Committee believes that there should be greater flexibility in the manner in which funds are spent. At present, funds are allocated on an annual basis. Funds not spent in any one year would be returned to the Consolidated Fund. This therefore leads to a system in which funds are spent regardless of whether or not a problem exists in any one year. The

Committee believes that there should be far greater flexibility in funding for rabbit management between seasons and in response to problems which may arise in any one season.

THE ECONOMICS OF RABBIT CONTROL

The Committee considers that there is an urgent need to critically review both the economics of present rabbit control methods, and to examine the question of "Who should pay".

For many years rabbit management has been supported by taxpayers. Your government's present economic policies and the current reductions in taxpayer input indicate that within a relatively short period of time the total cost of rabbit control might be carried by farmers on whose land rabbits are to be found.

The Committee supports the notion that beneficiaries should pay, but believes the question of "Who are the beneficiaries" needs careful examination. At present rabbit control is carried out for reasons relating to both land production and land protection.

Land production

Rabbit control for production can be viewed as a concern of producers. However this implies that producers have the right to use all least cost and effective methods available to them. Myxomatosis is a method widely believed to be both effective and cost-efficient in the short to medium term (10-30 years). It seems however that the New Zealand community may not favour the introduction of the myxoma virus. Therefore, if the community are to deny producers the right to use this method it would be reasonable for the community to bear the difference in cost between this method and the next best alternative. There are no known cheap alternatives to myxomatosis.

In summary, the Committee believes that there is a strong case for continued taxpayer input on the grounds that taxpayers may not at present approve of the introduction of the least costly method of control, and until such time as the technical problems raised in the environmental report have been overcome.

Land protection

Land and landscape protection is an important objective of pest management and control. The aim is to protect soil in order that future generations of New Zealanders and visitors might have the opportunity to make productive use of land and landscape. Clearly as future generations benefit from rabbit control measures it is reasonable for future generations to bear part of the costs of present control measures. Taxpayer input is the practical way of sharing cost between present and future beneficiaries. The Committee was very concerned at the high erosion risk to which rabbit-prone land has been exposed.

Institutional arrangements

The Committee believes that the Agricultural Pest Destruction Council (APDC) and the Pest Boards have fine records of achievement. However, despite past successes the Committee questions whether the present institutional arrangements are necessarily the most appropriate under present conditions or for the future. The Committee believes that it would now be appropriate to give serious consideration to major changes in the institutional arrangements for pest management and control.

This may be an opportune time to abandon the national approach to pest control and establish institutions for management on a regional basis through County Councils or Catchment Authorities.

APDC is not constituted in a way that will ensure the efficient allocation and use of public funds because the constituent demands of its broad membership do not reflect the wider public interest. Although the Committee supports management on a

regional basis, it believes nevertheless that the co-ordination of those activities is clearly the responsibility of central Government and a portion of public funds must be devoted to training, administration and extension activities.

A "new look" pest management organisation with more emphasis on protection of land, (perhaps incorporating responsibility for noxious weed management as well) warrants serious investigation. The Committee, under its terms of reference, would be pleased to convene meetings of interested parties, or provide more information.

Yours sincerely,

M.R. MURCHISON
Chairman"

The Parliamentary Under-Secretary to the Minister of Agriculture, Mr D.J. Butcher, in his address to the South Island Pest Destruction Board's Annual Conference at Te Anau, on 3 July 1986, confirmed the intention of Government to phase out taxpayers' input into pest destruction. He also indicated that he is keen to see some concrete proposals for the future within, say, six months, and suggested that the array of pest destruction organisations could 'put its collective heads together with the Institute and others interested in the future of pest control activities'.

The Agricultural Pest Destruction Council (APDC) has, in response, made proposals for re-structuring pest destruction. The APDC investigated the following options:

- shift the responsibility for pest destruction to County Councils, or wards of County Councils, or United Councils, or regional authorities, or Catchments Boards.

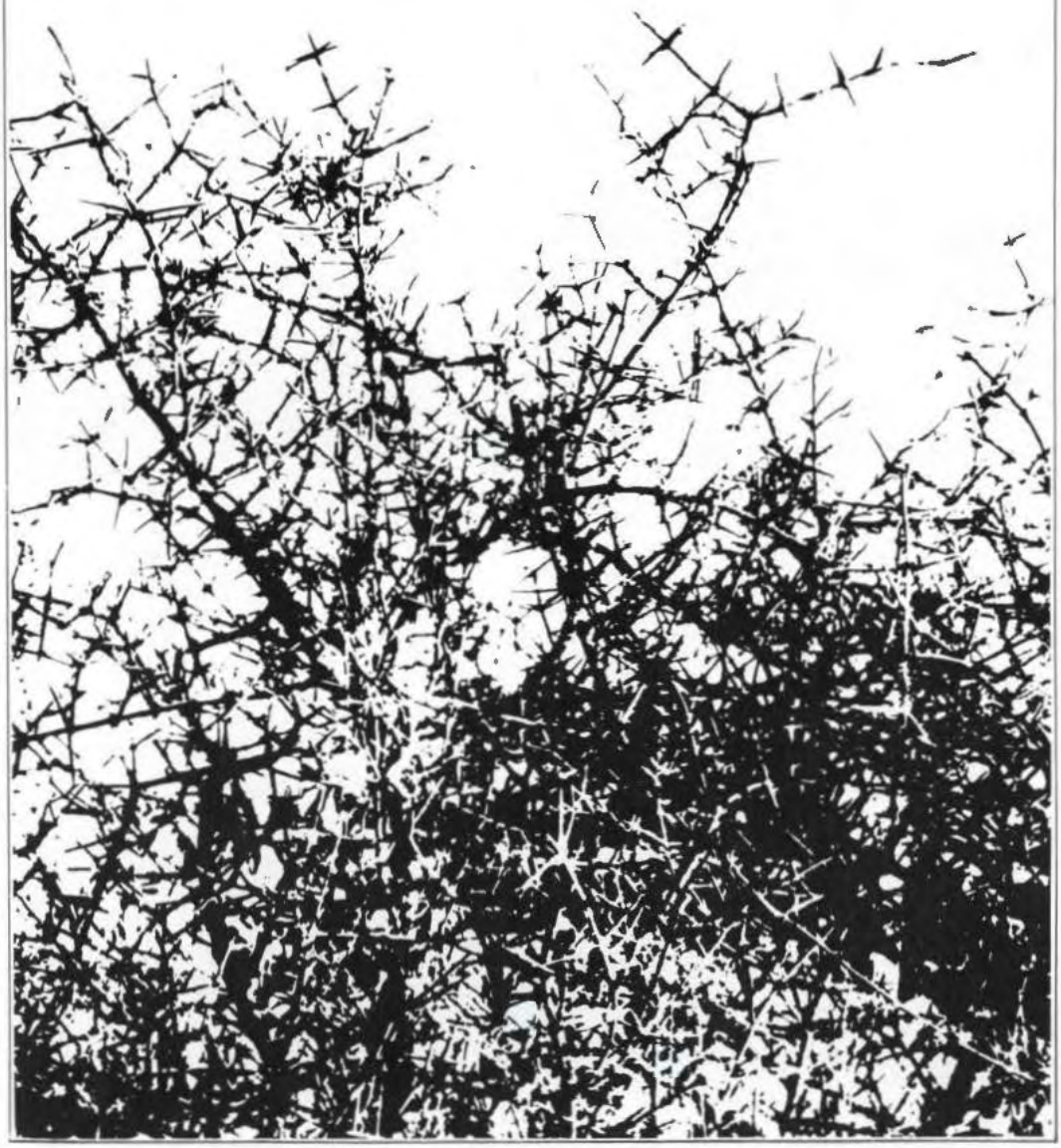
- create a new Land Protection Organisation incorporating functions such as the control of animal pests and noxious plants and catchment board functions related to protection of land from soil erosion.

- establish new Regional Pest Authorities (to recover and distribute taxpayer funding, combine work programmes of boards, and set priorities for taxpayer funding etc.) as a first step to ultimately setting up Land Protection Authorities.

The last option is favoured by the Agricultural Pest Destruction Council.

This topic is certain to be debated further.

Matagouri management



Matagouri — an introduction

I. G. Chris Kerr

For many years farmers, soil conservators and scientists have, for largely different reasons, expressed concerns about the management of matagouri (Discaria toumatou) on pastoral land. Affected farmers find they have a need to reduce dense matagouri because it restricts grazing and access. Soil conservators are concerned about the effects of (and containment of) fire on the land when fire is used as a means of control. Scientists with interests in botany, ecology and soils are seeking new knowledge about the plant as a means of establishing principles for its management.

Recently, during a period of rapid hill country farm development, more and more applications for burning permits for matagouri control were being made to catchment authorities in affected areas. Some authorities are considering reviewing the burning policies to ensure the objective and practice of the policies match current needs.

A workshop on matagouri, convened by three catchment authorities (North Canterbury, South Canterbury, and Waitaki), was held at Lake Tekapo in 1985. The objective of the workshop was to identify management options which could be promoted by catchment authorities as a means of achieving a sustainable land use in the presence of matagouri.

The workshop included topics covering the biology, distribution, control, and management of matagouri; and involved scientists, soil conservators, advisors, and farmers. Selected papers from the workshop are included in this edition of Review.

The programme for the last hill and high country seminar at Lincoln College included papers showing three different approaches to the management of matagouri. These papers, with some amendment, are also included in this edition of Review.

A review of a bibliography carried out as part of an overall review of the burning policy of the North Canterbury Catchment Board is also included. This is of special interest to those wishing to pursue studies in the topic.

It is hoped, by concentrating much of this issue of Review on matagouri, that a more widespread understanding of the plant is gained by many.

For pastoral land the options for the future are limited but in general it is clear that there are major benefits to pastoral farming and land stability through the retention of tall 'old man' matagouri which is usually not dense and is a feature of inland soils of comparatively recent origin.

It is concluded that the options for the management of short and dense matagouri are:

(a) burn or cut at regular intervals to reduce the size of the plant but expect early regrowth from the base of each plant which will again restrict grazing and access,

(b) allow the plants to grow and eventually thin out into a tall form under which native or improved pasture grows well and which provides shelter for stock,

(c) eliminate or thin out by cultivation, or by weedicide with the objective of establishing high producing pasture.

Each of these options have their costs and benefits. What is appropriate for one site may not be so for another. It is to be hoped that scientific knowledge, administrative policy and farmer practice can be reconciled to find a solution for each situation.

Matagouri control - the burning option

Philippa Grigg

Introduction

Matagouri has assumed weed proportion over many tussock grassland areas in recent times, principally where the plant has responded to phosphatic fertiliser and where control by burning has not been kept up. Reasons for not burning have been the increasing difficulty of the operation under improved conditions and lack of fuel, and also because it has been discouraged as being harmful.

The effects of burning are not well understood. Burning would be less controversial if the requirements of different types of country were better recognised and if this method for control of matagouri was known to be used at lower altitude where erosion is seldom involved. A liability or possible result of burning must be acknowledged in that fires may spread to higher altitude when the lower country is being treated.

Damage can be caused by fire at higher altitude of Kaikoura soil type and snow tussock country, particularly if the regrowth is allowed to be grazed. On the other hand the lower fescue tussock country of Hurunui soil type benefits where matagouri is checked by burning and the balance of competition between palatable and unpalatable plants is restored.

The decision to burn because of matagouri is made usually when production and management are seriously affected, a stage reached by gradual degree because this is a slow growing plant. Contrary to popular belief the operation is not easy, neither is it cheap when country has to be spelled to accumulate fuel to carry a fire.

Regulations

Burning may be carried out only under Catchment Board permit. Permits are issued subject to conditions such as area, altitude, time, boundaries, manpower available, notification and post-burn treatment. Each area is inspected before being recommended for Board approval, and there is a requirement to notify when the burn will be carried out.

The aim of Catchment Boards is to ensure that burning is necessary only once. The problem is knowing how to achieve this objective. Summer burning is being advocated as a method sure to kill matagouri but this has not been generally accepted or proved. Summer burning would seem to be dangerous - both at the time of the burn and when the fire can revive later.

In 1985 the South Canterbury Catchment Board approved 20 permits to burn 2,240 hectares, of which three-quarters were for matagouri control.

Conducting a burn

To save sufficient fuel to carry a fire, a block has to be spelled for most of a growing season. Where matagouri is dense, other plants may have been excluded to the extent that there will be insufficient fuel to get a good burn.

Good burning conditions are limited and occur in spring when drying winds have followed a succession of heavy frosts. The desiccated and dried vegetation is very inflammable. Later, when it is damp and rotted, or later on in the season when there is green fresh growth coming through, it is less flammable.

The safest conditions for burning are anticyclonic weather, still and with no general wind. There is, however, usually a wind of local influence - westerly early and easterly later in the day - and success of a burn can depend on correctly judging the time the wind will change. Some degree of nor'west wind is often used to carry fire when fuel is not plentiful, also the time is limited before a change from nor'west to southerly and damp weather occurs.

It is better to burn an entire block rather than part of it, because stock will tend to concentrate and graze on the burned area to the exclusion of the rest, which is to the detriment of both land and stock.

Bulldozed firebreaks are in general use but alone will not contain a front fire safely. More substantial breaks are made by backburning away from the dozed line into the wind. Shallow dozing will lessen subsequent erosion or soil wash, but if the break is not deep enough some surviving tussocks tend to be washed and blown clear thus making an incomplete break, with the danger that fire can trickle across undetected under cover of smoke.

Where a break is being reinforced by backburning the fire is usually beaten out because if left to run it can, even with a slight shift of wind, burn sideways then assault the break uphill further along. Where the backburn is left to run, those who are lighting have to hurry to complete the job, at the same time as being prepared to beat out any creep across the break.

Conducting burns in this way is relatively safe and in 20 years of operation we have kept fire at the lower altitude. Natural boundaries such as sparse ridge tops and rocky areas can be as effective as firebreaks. Where country is too steep to doze, fire is lit either downhill or upwind, allowed to burn away a strip, then beaten out with sacks. This can be slow and sometimes difficult process.

Cotton plant (Celmisia spectabilis) is often a problem because it burns a long time and may need to be grubbed out to make a break, otherwise it can smoulder and start again.

A snow cap is often considered but seldom used as a boundary because the shady faces, which need to be burned, hold the snow much later and do not clear. It seldom works on a local scale, but can be a safeguard to higher country.

Post-burn management

The most effective post-burn management is continuous grazing of high intensity. This should be continued for at least a complete growing season after burning to give the best control of young shoots before they harden and become unpalatable.

A hot burn, which removes sticks, is the most effective as it allows stock access to graze the regrowth, and cattle can be useful in knocking down and breaking up stick. It has been argued that a hot burn gives better control of regrowth, or that it can even kill the plant. A slow downhill burn of heavy vegetation ought to give better control, but this does not appear to differ in effect to lighter front burns. The plant has to grow again from the crown where the bark has been completely burned. Sprouting also occurs from the stem in large bushes. A second burn to destroy young regrowth has been suggested but it seems the practice is not followed.

Follow-up treatment of oversowing and topdressing is usually required for permits for an initial burn but seeding is not always needed on improved

country where clover and hard seed is present. Results seem to come more from the grasses already present such as danthonia, sweet vernal and browntop.

Effectiveness

The burning we have done to control matagouri has been successful in some areas, to the point of total eradication, whilst a failure on others. On the easier damper blocks of Surrey Hills matagouri has almost completely been removed, whereas the same methods have largely failed where applied to the steeper and drier country, even where fenced into small blocks. The reason for this is partly the difficulty of getting a good burn owing to lack of fuel where green growth comes through the improved pasture.

Control of matagouri has been a struggle on the more extensive Barrosa high country where for 20 years we have needed to repeat burn after five to eight years on 10 topdressed blocks of about 2000 hectares total area. This is an unsatisfactory state but, without burning, the carrying capacity has gone back to being as low as it was before it was even topdressed. It should be recognised that vegetation cover has greatly improved in this time as reflected in increased grazing capacity; on average from a ewe equivalent to two acres, to two to the acre.

Of continuing concern is the fact that in many areas matagouri is growing past the stage at which it can be controlled by fire and already much of the country has gone to scrub which has no fuel to provide a burn.

Other options

Matagouri can be valuable where it provides shelter and shade, breaks up snow and even allows some grass to grow underneath. There will, however, always be plenty around without consciously keeping it for that purpose.

The do-nothing option is like a slow time-bomb, which will go off. Perhaps the only merit of that approach is that matagouri grows only very slowly so that it can be lived with where it has not had fertiliser. Unfortunately, though, doing nothing is not a practical option because the weed hieracium is decimating most unimproved tussock grassland.

The increase of matagouri has forced us to consider spraying as an option and five years ago we started trials with chemicals donated by Ivan Watkins Dow. Rates lower than recommended have been tried to bring costs within reason, and at the same time we are prepared to accept less than a total kill. Lower rates of water and single pass flying have also been tested. An acceptable kill costs about $250 per hectare, which is still too high to be used at present product prices. But when it becomes economic, chemical spraying is likely to be the option used to control matagouri.

Conclusion

Burning can control matagouri but will seldom kill it, particularly where the plants have been strengthened by fertiliser over a period of time. Post-burning management designed to prevent regrowth has generally failed, except on some better class land. Burning must therefore be regarded as a holding operation, rather than a satisfactory method. However, as long as chemical spraying costs are not economic, there is no viable alternative to burning which can retain improved tussock grassland in production and prevent its transition into scrubland.

Matagouri control - chemicals

Brian A. Patterson

Not long after an extensive development programme was started on Manahune Station in 1973, a matagouri problem became apparent on the north-west faces of the developed area. I was concerned about the spread and growth of matagouri particularly in relation to possible further development work. So after building a properly calibrated spray machine, I began trial spraying in 1977-78.

The first trial, with gorse and matagouri, began in mid November 1977, with a break of several weeks in the middle of the operation. It became obvious very quickly that the first spraying in mid November had yielded significantly better results than the later spray.

The following year (1978), I observed the matagouri to be in full flower and leaf during the second week of November, at which time a helicopter sprayed 8.1 hectares on either side of a hill track that was becoming increasingly difficult to use because of a matagouri infestation. The top side of the track was sprayed with 22 litres of Tordon Brush Killer (at the old chemical rate) with 200 litres of water. The bottom side was sprayed at a rate of 11 litres with 200 litres of water, with a double pass. The outer edge was sprayed with one pass of five litres with 100 litres of water.

A 95% kill was achieved with the first two application rates (221:2001 and 111:2001, double pass), and a 45-50% kill was achieved with the lower rate.

The first detrimental result was the death of clover that had been established. But all broadleaf grasses - timothy, cocksfoot, rye and dogstail - grew far stronger. The growth of these grasses is a secondary benefit from spraying, and contributes to the viability of control by spraying.

After spraying, matagouri becomes very brittle, and during spring and summer stock are reluctant to graze sprayed areas. By winter time, the matagouri begins to rot at ground level and break down. In 1979, I put cows to winter on the trial sprayed area, to speed up the breaking down of the matagouri. This proved to be too hard on the cows.

I resisted the temptation to respray the matagouri that was still standing. Instead, in late autumn 1979 the whole block was closed, in order to winter graze with three hundred 18-month and two-year cattle. Their feed was supplemented with meadow hay. This system has several advantages:

- the cattle fed in a larger tighter mob, thereby trampling the standing matagouri.
- mob feeding opened up the area, letting hay seeds regenerate; and,
- use of young cattle made heifer selection much easier as the tighter grazing made those unable to compete easier to cull.

For comparison, I carried out trials on undeveloped country at the same time. It became obvious that matagouri that had not been fertilised was hard to kill.

TABLE 1: Cost of control.

Application rate	5l/ha	10l/ha
Two passes 220 l/ha	$247	$420
One pass 80 l/ha	$209	$382

Based on chemical cost of $34.65/l and on helicopter cost of $30.60/ha.

In its native state, matagouri bark is moss-covered. After two or three years fertilising, a lot of this mossy coat is lost, and new growth is more soft and green - allowing easier chemical penetration.

My conclusions from these trials are as follows:

- fertiliser must be applied two to three years before spraying;
- heavy stocking the winter before, and right up to spraying, is important to expose the matagouri plants;
- plants must be in full flower at spraying time, and;
- spraying is best done in overcast conditions, or early morning/late afternoon.

The costs are high, too high you may say. But, before chemical spraying matagouri cover on my hill blocks was 50%. I have no doubt that if left uncontrolled matagouri will take over, eventually reducing income per hectare to the point where control is not economically viable.

Financial outlay on chemicals is essential to obtain maximum returns of previous development costs. Unlike broom and gorse, matagouri requires only one chemical treatment for permanent control. The rate of application determines percentage kill. A rate of one litre of brushkiller per hectare applied with a handgun can give a 50-60% kill. Chemical 50D is a cheaper alternative that gives good results if used correctly.

My experience is that a total kill isn't necessary, or even desirable. Matagouri cover can protect the land from adverse climatic conditions.

Compared with most other control measures, brushkill chemicals can give matagouri control at an acceptable cost.

TABLE 2: Stock unit returns from chemical control.

	s.u.	$	Gross/ha
Before control	3.25	30	$97.50
After control	5.00	38	$190.00

Matagouri control – the do-nothing approach

Harry E. Pawsey

The 'do-nothing policy' on matagouri control is to take no active steps to control the plant. In the short term, this policy encourages matagouri to grow and prosper, to maximise long term benefits to the hill country farmer of a stable grassland of clover, grass, tussock and matagouri.

Property description

Situated on the Virginia Road about 20 kilometres west of Hawarden, Double Tops occupies 2705 hectares, of which 400 hectares are rolling cultivated downs, 1100 hectares improved tussock and the remaining land, native. Average rainfall is around 750 mm at the homestead and 800 mm at the western side of the property. The downs are about 500 m a.s.l., the highest point is 1000 m a.s.l. The hill soils are a mixture of the Hurunui and Haldon series.

We carry 5500 Corriedale ewes, 1300 hoggets, 200 breeding cows and replacements, a total of 8500 stock units. The lambing percentage in 1984 was 98% survival to sale and calving 90%. We clip 3.8 kg wool per sheep wintered.

In the past, the downs have been cultivated, but more recently development has been concentrated on the hill subdivision, using electric fencing and oversowing of clover, grasses and superphosphate. Good clover establishment has been achieved as well as some solid growth from matagouri.

I do not know if Double Tops had a matagouri problem in the past, or whether the current infestation is due to burning practised in the past. Today a large part of the hill, developed and native areas, carry a good cover of matagouri.

Matagouri

Matagouri is a low fertility colonising nitrogen-fixing shrub unpalatable to stock. Generally superphosphate applications on low fertility land will increase its growth. Matagouri is able to dominate because it is deep rooted, able to withstand moisture stress, and appears to be more tolerant of low soil pH than clover.

Matagouri does not like a vigorous sward of grass and clover growing hard up against its stump nor heavy concentrations of dung and urine. It responds by growing more upright, reducing the spread of ground runners, eventually becoming less vigorous.

The only long term solution to the problem of matagouri spread is to manage it in such a way that it is less able to dominate, and is eventually choked out. Until sufficient increase in fertility has occurred for this to happen, we have to live with matagouri.

The problem is that fertility build-up is very slow, and may not occur because of low rainfall, low pH and lack of development money. There may be a strong case to leave some sites alone, and accept low productivity from them.

Is matagouri a problem?

A walk through matagouri-infested

tussock will soon convince most observers (apart from perhaps the pure conservationist) that matagouri is a problem. Scratched legs testify to its menace. But apart from the nuisance value the question still remains, do the disadvantages of this plant outweigh its advantages? If matagouri is a problem will the control measures taken to contain the plant be effective or economically viable?

Disadvantages

Reduces land for grazing Dense, scrubby matagouri hinders stock mobility. Animals are reluctant to graze around it, leading to rank growth which in time become impenetrable. This usually occurs as a result of an ambitious development programme, when the area of land topdressed exceeds available grazing control.

Mustering difficulties Matagouri bushes provide cover for straggling sheep, making the musterer's job more difficult and time consuming.

Reduced wool returns Sheep grazed on matagouri country prior to summer shearing can get considerable matagouri debris caught in the fleece, which may lead to a reduced wool price. At Double Tops sheep that have been on the hill prior to shearing in February have a tested vegetable matter content of up to 1.5% compared with sheep in the paddocks which have 0.2%. Hill sheep wool prices can be discounted by up to 15 cents per kilogram.

Matagouri also seems to be an effective wool harvester. Plucked wool may not be a significant percentage of the total wool clip of summer-shorn sheep, but may be more significant in late winter with pre-lamb shorn ewes that have suffered stress and developed a wool break, so belly and flank wool is easily plucked by matagouri.

Scabby mouth Lambs of ewes from matagouri infested country can have a high incidence of scabby mouth. In severe cases scabby mouth reduces lamb growth, but more importantly the freezing works will not accept stock for slaughter when scabby sheep are present. A three-week delay can occur while scabs heal.

Advantages

Microclimate Matagouri, like tussock, can provide a microclimate suitable for developing pasture plants. Tall matagouri provides considerable shelter from the nor'west wind.

Lambing and calving shelter Matagouri provides excellent shelter for stock giving birth. At Double Tops similar lambing percentages have been achieved by stock left on their own on the hill and those on intensively lambed paddocks. Tall matagouri can provide newborn animals with considerable shelter from strong north-west wind and rain. Also, compared with well covered hill blocks of the same aspect, blocks bared by fire yield depressed final tailing percentages.

Snow recovery Fortunately, Double Tops is not troubled by snow. On the higher country we receive about three or four falls a year of up to 30 cm deep, that can lie around for a week or two. The first grazing available to stock caught in heavy snow is that uncovered by matagouri springing up from under the snow mantle.

Matagouri can also provide useful footing for cattle walking round snow-covered or wet and greasy slopes.

Soil stability On steep rubbly or scree slopes the top batter of a new track takes years to consolidate, usually only after the matagouri has re-established a new root system. I often wonder what would happen to the scree gulleys if matagouri was not there to stabilise the surface with its deep root system.

Feed reserve Unless stock are forced onto matagouri most do not graze too close to matagouri. This can result in a feed reserve building up under the matagouri umbrella during spring, which can be harvested later by hungry animals, should a drought occur.

Comparison

It is difficult to quantify the advantages and disadvantages of matagouri. The obvious financial cost to sheep farmers is that of a reduced return from wool because of moit and wool 'harvested' by the plants. Because we shear in February, wool loss is negligible, though wool from hill ewes can be discounted by up to 15 cents per kilogram. The financial cost to us from this could be as much as $1560 per year (3000 ewes at 52 cents discount).

In my view matagouri does not present sufficient menace to warrant eradication. Furthermore, I consider that matagouri has enough overall advantages for its presence to be beneficial.

In my experience chemical control of matagouri is too expensive. Burning seems to give only a respite and exacerbate the long term problem. I have burned matagouri and obtained a temporary clearance, but have ended up with a worse problem. I have also burned shady faces before oversowing, but again, the matagouri has returned.

When land is denuded, ground cover that is best suited to the environment re-establishes itself. In some situations, such as on a north-west face, desirable grasses may be too exposed to thrive, so such plants as matagouri and thistles might become the colonising plants. In such conditions, it may be preferable to hoof and tooth, rather than burn, establish clover and grass, then spot burn areas of rank growth, the aim being to establish a natural harmonious balance between introduced and native species.

Management

My approach to the problem of matagouri infestation and hill development is to fence according to aspect and soil type. Each block of land should be individually assessed for the best land use. The best cover for grazing is sparse tall matagouri, tussock, clover and grasses. Should it appear that topdressing will result in dense matagouri growth, consider whether the matagouri will grow up and allow the stock to graze underneath. If the conclusion is that topdressing will result in dense low form matagouri, then that block is best left as it is or planted in trees.

Subdivision

The usual complaint about matagouri is that hill blocks become overgrown, preventing sheep from grazing the entire block. Set stocked sheep in large blocks favour certain areas and neglect the shady aspects which become rank.

We have found that 4500 ewes mob grazing 80 hectare blocks fenced according to aspect will graze most of the block, criss-crossing the areas of tagg, forming tracks. The next time round these tracks become more numerous and wider and verged with shorter more palatable grass and clover. The matagouri then becomes confined to the tagg and grows more upright.

Cattle, when held on small blocks, will graze hard into matagouri tagg, particularly in the autumn and early winter.

Considerable progress can be made in controlling tagg when stock are mobstocked all year round. However, forcing pregnant stock into tagg does not achieve satisfactory production. Mobstocking is possible only after weaning for a short period (so that ewes do not lose liveweight prior to tupping) and in winter. Cattle are very useful for keeping tussockland open over the spring.

Matagouri control is highly dependent on the level of subdivision. The more fencing, the better the control.

Fertiliser

Matagouri shows a good response to superphosphate. In the past I have made the mistake of stopping topdressing of matagouri-infested faces, thinking I was throwing money away growing more prickles. Normal

topdressing of improved blocks should continue irrespective of matagouri infestation. Fertiliser encourages matagouri to grow tall, thereby letting stock in to the sheltered pasture beneath. In time, improved fertility results in choking out of weaker matagouri, leaving a nutritious sheltered grazing block.

Avoid burning

I have yet to see a burn that has killed matagouri. In my observation, burning converts matagouri from an upright plant to a prostrate shrub, and delays the long term establishment of a balanced pasture interspersed with tall matagouri.

The only justification for burning is to clear the mustering off points from hill blocks.

Conclusion

To summarise, I consider that matagouri has advantages to the hill country farmer. Matagouri is a low fertility colonising shrub that responds to superphosphate and is better able to withstand climatic adversity than exotic legumes. In development, provided that hill country is adequately subdivided according to aspect, matagouri can be encouraged to grow tall and provide a microclimate for desirable plants and shelter for stock.

Matagouri can get out of control, usually in a man-made situation, where land has been topdressed without sufficient follow-up grazing control. Given good grazing technique and regular topdressing, soil fertility will rise, leading to a reduction in matagouri density on sites where it appears difficult to improve soil fertility, the best land use may well be either a low input, a low stocking rate grazing system or forestry.

My final message is to put up with the nuisance of matagouri in the short term, keep fencing and topdressing and in the long term matagouri will be your friend.

The distribution of matagouri (Discaria toumatou) in New Zealand

Grant G. Hunter

Matagouri, or wild Irishman, is an indigenous shrub widespread in the eastern South Island where it occurs in thickets or as an open shrub canopy in grassland. It is abundant on freely drained soils associated with slope deposits, fans and floodplains and especially on northerly-aspect slopes.

Matagouri has a divaricate, reduced-leaved habit, often considered to be an adaptation to a moisture-deficient, desiccating environment typical of most of its natural range. The roots of matagouri are nodulated and the species fixes nitrogen, a feature which enhances its role as a coloniser on N-deficient soils (Daly, 1969).

Mature stands of matagouri often comprise spaced, thick-stemmed low trees, but immature stands typically form thickets. In terms of pastoralism, the dominant land use throughout most of the plant's natural range, matagouri is both an asset and an adversary. As a coloniser, matagouri can grow on sites where little else is able to grow, stabilising soils and possibly enhancing N status (Daly, 1969). The shrub can provide shade and shelter for pasture and stock and inhibit snow-lie (Dingwall, 1965). However, the establishment or expansion of thickets in grassland, especially on land fertilised for pasture improvement, is of concern to many hill and high country farmers because of loss of grazing land and inhibition of stock movement (Daly, 1969).

The distribution of matagouri on farmland in the South Island, and the associated weed status perceived by farmers, has been mapped by Bascand and Jowett (1981, 1982). In this article, the general distribution of matagouri in New Zealand is evaluated in terms of soils, slope, associated vegetation and rainfall. The impact of matagouri on land use is discussed.

Collection of information

Material presented in this article was derived from the New Zealand Land Resource Inventory (NZLRI). In that survey, five factors - rock type, soil, slope, erosion and vegetation cover - were mapped, using a homogeneous map unit approach, at a scale of 1:63360 (one mile to one inch), NWASCO (1979).

The vegetation cover classification used in the NZLRI was established, as far as possible, to identify plant species or communities of national importance in terms of rural land management. Matagouri was one of 13 scrub classes. The general vegetative cover within each of approximately 90,000 map units, determined by visual estimates of cover from aerial photographs and during field work, was recorded. Matagouri was recorded in those map units where it was estimated to be a major species or where it was visually prominent over all or part of the area.

Scrub communities classified in the NZLRI as "matagouri" were diverse and included both nearly monospecific stands of matagouri scrub or shrubland over grassland and communities with other

divaricate shrub species including Corokia cotoneaster, Coprosma propinqua, pohuehue (Muehlenbeckia spp.) prostrate and small leaved kowhai (Sophora spp.) and native broom (Carmichaelia spp.). In moist foothill districts matagouri is commonly associated with broad-leaved shrubs including wineberry and Olearia spp. (Hunter and Blaschke, in press).

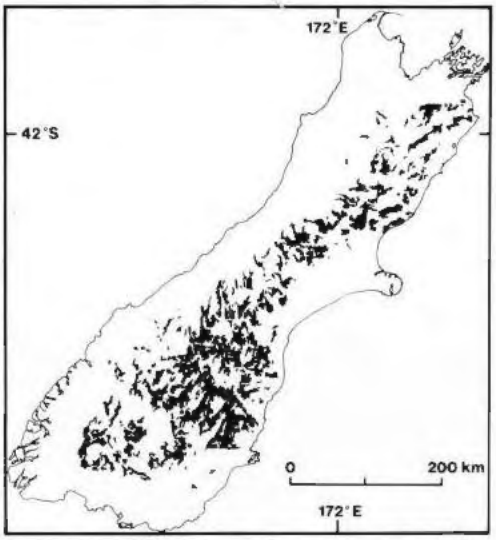


FIGURE 1: The major areas in which matagouri is recorded in the South Island, New Zealand. The boundaries of all map units in the New Zealand Land Resource Inventory that contain a record of matagouri are plotted to scale.

The distribution of matagouri

Matagouri was recorded within 3400 map units covering 1,191,200 hectares. It was recorded extensively in the hill and high country and associated intermontane basins in the eastern South Island, from the Wairau River in Marlborough to northern Southland (Fig. 1, Table 1). Its western extent was in the central valleys of the major rivers flowing eastward from the main divide, although it was recorded sparsely on valley floors close to the headwaters of these rivers.

The shrub was recorded sparsely in Westland and Nelson, almost exclusively on floodplains and fans in mid and upper valleys such as the upper Buller. Although matagouri is locally present in the North Island, especially on coastal sand dunes (Elder, 1966), it was not of sufficient extent to have been recorded in the NZLRI. Historically, matagouri was more extensive within some parts of its present geographic range. In particular it has been obliterated in land developed for intensive agriculture such as the Canterbury Plains (Crawford, 1949).

Only the major areas of matagouri are mapped in the NZLRI. Where the plant is sparse and forms little of the plant canopy, where small plants escaped detection in grassland, or where it is a minor species in diverse plant communities, it was unrecorded. For example, none was recorded on Banks Peninsula even though it is present on many northerly-aspect slopes.

Using a combination of stratified field sampling and subjective field observation, Bascand and Jowett (1981, 1982) have documented a similarly extensive distribution of matagouri in Canterbury, Otago, Southland and Marlborough. On a regional basis, the percentage of land recorded by Bascand and Jowett (1981) as covered by matagouri ranged from 10.5 to 20% of NZLRI map units containing matagouri. The two results appear similar because matagouri was generally a minor vegetation cover class, covering between approximately five and 40% of the NZLRI map unit area within which the shrub was recorded.

Matagouri was recorded mainly on soils derived from greywacke and schist parent material, and locally on soils derived from minor rock types including limestones and other Tertiary sediments and volcanic rocks.

Fifty-five percent of land with matagouri belonged to the brown-grey

earth and yellow-grey earth soil groups (Tables 2 and 3). These occur in semi-arid to subhumid eastern lowland districts, inland basins and the high country fringe where the annual rainfall is generally below 800 mm. These weakly to moderately weathered soils have a relatively high nutrient status and are characterised by a pronounced summer soil moisture deficit. Soils in the yellow-grey earth/yellow-brown earths intergrade and lowland yellow-brown earths group are more strongly leached, and the reduced extent of matagouri in these groups is probably controlled by a combination of lower soil nutrient status and increased competition from other plant species. Although the cold-climate upland and high country yellow-brown earth soils cover a wide rainfall range, matagouri was most extensive in this soil group in localities with relatively low annual rainfall. Matagouri was also recorded on recent soils on floodplains and fans in both lowland and high country

TABLE 1: The extent of map units containing matagouri by region and county.

Region	County[1]	Area containing matagouri (ha)		% of South Island total
Westland	Inangahua	400		
	Westland	100		
Total			500	0
Nelson	Waimea	2200		
Total			2200	0.2
Marlborough	Kaikoura	14700		
	Marlborough	84900		
Total			99600	8.4
Canterbury	Amuri	45000		
	Ashburton	24300		
	Cheviot	15200		
	Hurunui	73500		
	Mackenzie	98000		
	Malvern	68900		
	Oxford	4400		
	Strathallan	14700		
	Waimate	78900		
Total			422900	35.5
Otago	Bruce	1500		
	Clutha	900		
	Lake	38800		
	Maniototo	111800		
	Silver Peaks	60000		
	Tuapeka	41400		
	Vincent	148900		
	Waihemo	39400		
	Waitaki	103000		
Total			545700	45.8
Southland	Southland	57900		
	Wallace	62500		
Total			120400	10.1

[1] Counties with no recorded matagouri are not listed.

environments.

Within the soil groups and sets, the distribution and vigour of matagouri is not uniform but is determined by variations in soil properties. For example, the physical and chemical status of upland and high country yellow-brown earth soils in the eastern high country, even within a map unit, is diverse, related to landform and cycles of erosion and soil development. Recent soils, rich in available phosphate occur close to old, leached soils and eroded soils with exposed B horizons. In these conditions, matagouri is often strikingly confined to rejuvenated situations, including lower scree margins, fans, debris flows and colluvium. These landforms are often irrigated by subsurface moisture, a further factor influencing matagouri vigour and possibly distribution (Daly, 1967). In the yellow-grey earths, matagouri tends to be more uniformly distributed while being especially extensive or vigorous on toe slopes comprised of accumulating colluvial deposits.

Matagouri was mapped on a wide range of slopes and associated landforms. Sixty percent was recorded on moderately steep to steep (greater than 20^{o}) hill and mountain land; 23% was on moderate slopes ($8-20^{o}$), typically lower footslopes and fans; and 17% was on flat or gently sloping (less than 8^{o}) floodplains, terraces and fans. However, for the entire South Island, the proportion of land in these slope groups is approximately 60, 16 and 24% respectively. Assuming that distribution of slopes within the geographic range of matagouri are similar to that for the whole of the South Island, slope or slope-related factors alone do not appear to strongly influence the distribution of matagouri.

The upper-altitude limit of land supporting matagouri was almost always below the 1000 m altitude contour, and it often extended below 500 m, especially in the inland basins and in Southland. This firmly places its main distribution within the montane altitude zone which has its upper limit at approximately 950 m, even though the species is commonly found upslope in the colder-climate lower subalpine zone (Wilson, 1976).

Matagouri was most often recorded as

TABLE 2: The distribution of matagouri by soil group and annual rainfall.

Soil group	Annual rainfall (mm) <800	800-1600	>1600
	Area (ha)		
Brown-grey earths	55 800	1 400	0
Yellow-grey earths	328 300	193 900	9 100
YGE/YBE intergrade	8 000	34 500	300
Lowland Yellow-brown earths	20 600	127 800	4 600
Upland and high country YBE	44 000	167 800	70 000
Rendzina and related	3 300	2 500	-
Brown granular loams and clays and BGL and C/YBE intergrade	10 600	9 700	500
Yellow-brown loams	6 400	0	
Gley recent	2 700	500	200
Recent	25 200	36 300	27 600
Total	504 900	574 400	112 300
% of total	42.4	48.2	9.2

minor scrub in short tussock or other unimproved grassland (Table 4). It was recorded as the dominant vegetation cover on only 7100 hectares. Within map units matagouri tends to be localised and it is beyond the scope of the inventory to delineate relatively small tracts of matagouri-dominant terrain. Matagouri was extensively mapped in combination with other scrub classes; sweet brier (206,700 ha), manuka/kanuka (116,700 ha), bracken (94,600 ha) and less extensively with Cassinia (23,500 ha), mixed indigenous scrub (21,000 ha), broom (19,800 ha), gorse (3800 ha) and subalpine scrub 3300 ha), in most cases in grassland-dominated vegetation. Although these scrub species were recorded together within map units in the NZLRI, it is not possible to determine where they occurred as mixed plant communities and where they existed as separate entities.

These analyses confirm that matagouri is well adapted to, and occurs extensively in, a range of landforms in low to moderate rainfall districts of the South Island. It forms a minor but sometimes locally concentrated scrub element in the tussock grasslands of the montane altitude zone. In higher rainfall districts its extent may be limited by low fertility soils, associated with strong leaching, and competition from other plant species. In those districts it is largely limited, as colonising vegetation, to rejuvenated, recent soils such as those on fans, floodplains and scree margins.

Land use implications

This paper examines the distribution of matagouri the "plant", not matagouri the "weed". Throughout its range, the species fulfils a number of roles. As a coloniser it may enhance soil properties.

On other sites its ecological status enables it to compete successfully with more agriculturally productive plants and is thereby regarded as a weed.

Bascand and Jowett (1982) attempted to evaluate the problem status of matagouri perceived by farmers. In general, farmers regarded it as a minor to serious weed problem in much of the terrain where they estimated that it covered more than four percent of land that can be farmed.

NZLRI vegetation cover data is unable

TABLE 3: The major soil sets supporting matagouri scrub.

Soil group	Brown-grey earths	Yellow-grey earth	YGE/YBE intergrade	Lowland YBE	Upland and high country YBE (& minor podsolized soils)	Rendzina and related	Brown granular loams, Brown granular loams and clays to YBE intergrade. Yellow-brown loams.	Recent (minor gley recent)
Main soil sets[1]	Conroy Conroy Hill	Oturehua Tima Hill	Kakahu Mossburn Hill	Kaihiku Hill Te Mara Hill	Tekapo Tekapo Hill	(Waikari Hill)	(Camphill-Becks Hill	(Dobson)
	Clare Alexandra Stp. Waitaki Stp.	Tiroiti Hill Blackstone Blackstone Hill Meyer Hill Matarae Matarae Hill Arrow Stp. Omarama Stp. Hakataramea Weld Stp. Opuha Hill Pukerangi Pukerangi Hill Naseby Haldon STp. Tengawai Stp. Tengawai Hill		Hurunui Stp. Hurunui Hill Silver Peaks Stp. Tuapeka Hill	Ohau Muller Craigieburn Cass Cass Hill Katrine Wehenga Hill Taringatura Hill Kaikoura Stp. Tekoa Stp. Tekoa Hill Fairlight Stp. (Lewis Stp.)		(Malakoff Hill) (Twinlaw Stp.) (Dunton Hill)	Eweburn Gladbrook Tasman

[1] Soil sets (New Zealand Soil Bureau 1968) with greater than 5 000 ha mapped as containing matagouri are listed in numerical sequence. Soil sets in brackets are the major sets in the group but which cover less than 5 000 ha.

to further clarify the weed status of matagouri. It does not distinguish between clumped and scattered vegetation patterns, nor does it interpret vegetation dynamics. For example, a record of "short tussock grassland with minor matagouri" in a map unit can cover several situations: matagouri confined to localised, stable pockets within grassland; scattered old-man matagouri dispersed throughout grassland; or matagouri in the early stages of vigorously invading top-dressed grassland.

TABLE 4: The regional distribution of matagouri according to the dominant mapped vegetation cover class.

	Region							
	Westland	Nelson	Marlborough	Canterbury	Otago	Southland	South Island Total	% of South Island
Dominant vegetation cover	Area (ha)							
Grassland								
High producing pasture	400		3 100	27 200	25 700	11 400	67 800	5.7
Short tussock and other unimproved grassland[1]	100	220	92 200	349 400	493 800	96 600	1 034 300	86.8
Snow tussock grassland			1 300	40 600	18 800	100	60 800	5.1
Red tussock				700	600	11 100	12 400	1.0
Scrub								
Manuka, Kanuka			1 800	800	400	200	3 200	0.3
Matagouri			400	3 300	3 400		7 100	0.6
Other indigenous scrub (Cassinia, fern, subalpine, mixed indigenous)			700	400	1 300	800	3 200	0.3
Exotic scrub (broom, gorse, sweet brier)			100	400	600		1 100	0.1
Forest								
Beech					700	200	900	0.1
Exotic conifer				100	300		400	0
Total	500	2 200	99 600	422 900	545 600	120 400	1 191 200	

[1] "Short tussock and other unimproved grassland" includes all grassland, except snow tussock or red tussock (Chionochloa spp.) which has no prominent sown, high yielding agricultural species. Most is characterized by hard tussock (Festuca novae-zelandiae) or silver tussock (Poa laevis), but communities with sparse tussock are included. Browntop, sweet vernal and a number of "flat-weeds" are common species.

TABLE 5: The regional distribution of matagouri according to land use capability class.

	Land use capability class						
	III	IV	V	VI	VII	VIII	Total
Region	Area (ha)						
Westland		400		100			500
Nelson		1 400		800			2 200
Marlborough	600	900	300	65 000	24 500	8 100	99 400
Canterbury	2 800	42 900	800	279 000	87 100	10 200	422 800
Otago	16 400	76 800	2 800	333 100	110 400	6 100	545 500
Southland	4 600	21 000	500	90 000	3 700	700	120 500
Total South Island	24 400	143 400	4 400	768 000	225 700	25 100	1 191 000
% of total area in South Island with matagouri	2.0	12.0	0.3	64.5	10.0	2.1	
% of total of each LUC class in South Island mapped with matagouri	1.7	9.8	3.8	22.9	7.9	0.5	8.2

Nearly two thirds of the area of land supporting matagouri was recorded on land use Capability Class VI land; non-arable land with moderate limitations to sustained production under grassland or forest (Table 5) (SC and RCC, 1971). In the eastern South Island, Class VI land typically supports extensive to semi-intensive grazing on unimproved or semi-improved grassland, with smaller areas of high producing pasture, forest and scrub. An analysis of slope groups within the Class VI land supporting matagouri showed that most is hill country and steepland, with some easy-sloping land on terraces, fans and downland. The 21.1% on Class VII and VIII land was almost exclusively on steep terrain with soil, slope or climatic limitations that severely limit its versatility and carrying capacity (Table 6). Fourteen percent was recorded on arable land, comprising flat to gently sloping terrain with relatively deep, versatile, productive soils.

Matagouri the weed is likely to be mainly confined to Class VI land, on which it may displace significant numbers of stock. On arable land, it will be easily eliminated by intensive development and management. On Class VII and VIII land there is limited opportunity for pasture improvement, potential carrying capacities are low (Table 6), and matagouri probably almost exclusively forms beneficial and relatively stable plant communities. However, there is concern that matagouri spreads, even on marginal grazing land, in response to reduced or zero grazing and that it may be a fire hazard. For all classes of land, the differences between present average carrying capacity and top farmer or attainable physical potential estimates (Table 6) are due to many management factors, one of which may be the presence of matagouri.

Acknowledgements

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TABLE 6: Typical stock carrying capacity estimates for land containing matagouri.

Type of Land	Carrying capacity (ewe equivalents per ha)[1]		
	present average	top farmer	attainable physical potential
arable (LUC classes, III, IV)	2-11	5-14	8-17
non-arable			
-with slight to moderate limitations to sustained use (LUC classes V, VI)	0.5-8	1-12	2-14
-with severe to extreme limitations to sustained use (LUC classes VII, VIII)	0-1	0-2	0-4

[1] Based on estimates of carrying capacity indexed to land use capability units in the NZLRI.

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Management perspectives

Brian P. J. Molloy

Towards the Main Divide populations of tall 'old man' matagouri up to 100 or more years old are found on alluvial sites. These populations probably date from some catastrophic event in the mountains, such as regional or widespread storms and floods.

On rocky cone-like terrain matagouri is found in scrub associations with other woody plants (Coprosma, Corokia, Olearia and sweet brier). These tightly knit rubble scrub communities can sometimes be quite impenetrable. Many of these scrub populations are 75-100 years old.

The third type commonly found on hill and high country is short shrubby matagouri on fairly easy slopes - classed as good grazing country. These populations consist mainly of young plants which on most soils readily respond to fertiliser.

Burning causes a new set of problems. Conventional burns in late winter to spring favour matagouri regrowth. Controlled burning in late summer or autumn when most plant damage will be done should be considered as a future management option, if burning is considered essential.

Grazing animals will seek out resprouting plants but under low stocking intensities plants ultimately recover. Intensive grazing, perhaps behind electric fences, is essential to control matagouri regrowth from winter/spring burns.

I believe we won't beat matagouri with existing burning and grazing practices. Burning when the sap is low and plants are dormant can be likened to a winter prune. Summer-autumn, when the plants are still active and a hot fire is assured, is more likely to be successful in killing matagouri directly. But other factors have to be taken into account before this seemingly drastic measure is adopted widely.

Editor's note
This author feels that the following references make an important contribution to the literature on matagouri.

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Lex C. Reid

South Canterbury Catchment Board (SCCB) records show 60% of the burning permits issued in the last five years were for matagouri control. There is a trend towards repeated burning - every five to 10 years. There is a potential matagouri problem on 13,000 hectares in the Board's area. Because of the trend towards burning as a control measure, in 1979 the S.C.C.B. set up herbicide trials for the control of matagouri.

Repeated burning is not in the interests of soil conservation. It weakens desirable and undesirable plants, soil organic matter is lost and the risk of erosion increases. Also, when blocks are closed for burning increased grazing pressure is put on the remainder of a run.

Poor burns often occur because of insufficient fuel and unsatisfactory weather conditions at the time of burning.

Many blocks are too large to allow adequate grazing pressure after burning. Small blocks are easier to manage and can be grazed intensively, i.e. up to 100 dry sheep per hectare for two or three weeks. If grazing follows burning, shearing dates may have to be changed to avoid damage to sheared wool.

Another benefit of small blocks is that they can be shut up, to allow accumulation of fuel, with minimal impact on feed supplies of the property.

Fergus M. Sutherland

Matagouri is a problem in certain areas of Southland but does not appear to be spreading. It is present in the northern districts (Kingston, Lumsden) and around the Takitimu Range where it is confined to small fans.

Spring has been the traditional time for burning although Board policy allows for burning in the May-September period. There is some rotary slashing but this has not been very successful.

Excellent control has been achieved in Lands and Survey trials where small blocks have been oversown in the spring and burnt the following autumn.

Ray K. Maw

Background
The North Canterbury Catchment Board administers burning control over 1.2 million hectares of hill and high country land within the 1.9 million hectares of its district.

Burning permits issued during the last 15 years show an average three-fold increase in the area burnt each season. To put this in perspective however, this represents only 0.4% of the total area of hill and high country. The seasonal range for permits has been as low as 1838 hectares and as high as 11,211 hectares. It should also be noted that the major increase has occurred during the last five years. Within this period there has been the operation of Land Development Encouragement Loans from central government, and a public relations exercise by the Board about its burning policy.

Matagouri accounts for about half the area burnt each year, about 4500 hectares annually. According to the Ministry of Works and Development's Land Resource Inventory information there are about 210,000 hectares of matagouri in the hill and high country zone. Thus, the 4500 hectares burnt each year represents only two percent of the total resource.

The present situation
The following are observations about the Board's matagouri burning policy:

- Burning is generally carried out during a safe time of the year (spring) when soil conditions are not conducive to hard burning;
- As a result, matagouri is checked rather than eliminated;
- Oversowing and/or topdressing tends to increase the vigour of matagouri, as well as ground cover; and,
- One concern is whether the three-fold increase in area burnt is acceptable even though this represents only two percent of the total area.

Present management practices maintain a manageable matagouri population, at little cost to the farmer, little damage to soil stability and some reduction in tussock content of grassland.

Conclusion
The spring burning of matagouri meets the Board's requirement that soil erosion is not accelerated through unsafe burning practices.

However, in facing the land management issues concerning matagouri control, I ask:

- Is burning an acceptable management practice for these times?;
- What are the positive and negative aspects of burning on the soil resource with regard to -
  (a) frequency of burning;
  (b) fertility status; and
  (c) soil erosion?,
- How can we encourage sound weed management techniques - monetary incentives, extension efforts, or both?

Malcolm H. Douglas

Ministry of Agriculture and Fisheries has one trial on matagouri in the Southern Region, using goats stocked at 4.5, 5.5 and 6.5 per hectare with a constant 10 sheep per hectare. All groups are set stocked. The area was burnt, oversown and topdressed.

The control group of sheep have had no impact, whereas the two top stocking rates are having a considerable effect after one year.

Jeromy R. I. Cuff

The South Canterbury Catchment Board is concerned about repeated burning for matagouri control because of possible on-site soil damage and the risk of fire spreading to more sensitive snow tussock country at higher altitudes. The Board is anxious to see suitable control measures developed because of the reduced carrying capacity of matagouri-infected country and consequent higher grazing pressure on blocks at higher altitude.

Chemical trials with Tordon-based products have shown that the optimum time for spraying is November/December when matagouri is in full flower. The lowest rate used (c10 l/ha Brushkiller 520 plus diesel) gave up to 95% kill of high dense matagouri. Granules must be applied earlier (September). A 90% kill was achieved with a rate of 3 kg a.i./ha. This left some plants for shade and shelter. Clover mortality occurred with all treatments; however, clover re-established within two years.

Spray treatment of regrowth from burnt stumps was not successful. Grazing trials after burning showed that stocking rates of 10-12 stock units per hectare kept regrowth in a soft palatable form. Under this stocking rate plants were killed in four to five years. Burnt areas were first opened up by cattle which knocked over burnt plants and allowed sheep access to stump regrowth.

Summary

Ensure grazing blocks are small enough to allow adequate grazing control.
Blocks should be closed early (autumn) to provide fuel to carry a fire.
Follow burning with grazing, using cattle first then sheep or goats.
Spraying should be considered on small dense blocks.

Some questions that remain are:
How can a hot safe fire be guaranteed?
What are the grazing systems required to keep regrowth in a soft form and to deplete root reserves?

Hamish R. Ensor

From a runholder's point of view matagouri can be controlled using fire, oversowing and topdressing followed by spring stocking, if only a small area is tackled each year. If heavy spring stock control does not occur in every year during the first five following a burn, the cause is lost.

In theory, hot summer burns are the answer, but escape is a real risk and steps must be taken to contain the fire. One advantage of a summer burn is that the area can be sown the following autumn, and this would eliminate the weed problem which accompanies a spring burn and autumn oversowing.

Cutting for heavy grazing of the boundaries is a necessary part of pre-burn planning. If cutting is used to control matagouri the stumps must be painted with a mixture of 1/3 Tordon and 2/3 Diesel.

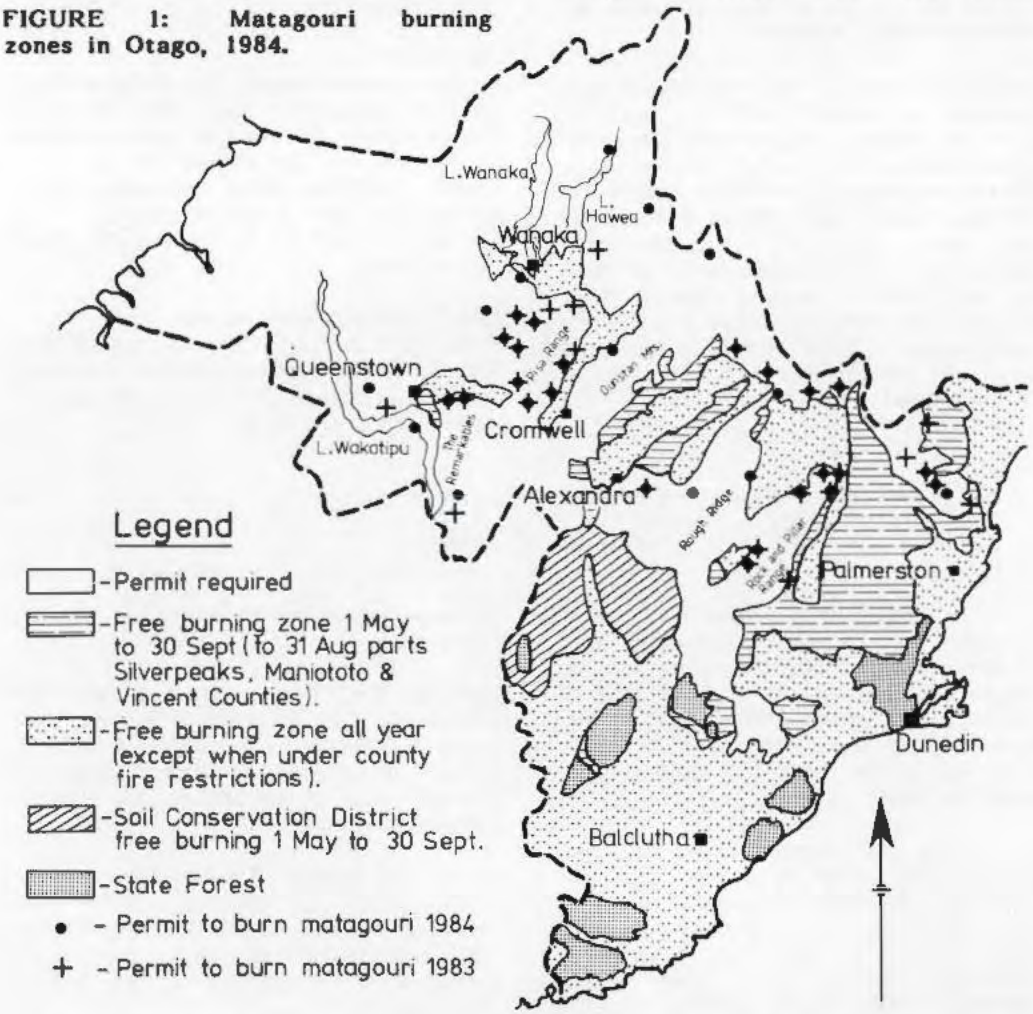
To a hill country farmer facing snow risks, there is nothing better for breaking snow than the bush matagouri, and nothing worse than the short whippy form - a problem at any time of the year.

Matagouri in Otago, while widespread, is largely absent from the higher rainfall areas in the west and south, and most is present in the drier north and central Otago areas.

Analysis of the Land Resource Inventory Work Sheets shows matagouri is present on 13% of the Otago Catchment District. It is dominant on only 0.1% and is the only vegetation mapped on 51 hectares (1 unit). Matagouri is mapped generally as a minor subdominant vegetation type (species).

Virtually without exception, matagouri is present in association with grassland vegetation. Eighty-seven percent of matagouri-affected areas are either

FIGURE 1: Matagouri burning zones in Otago, 1984.



Otago Catchment Board and Regional Water Board District
1980

dominant short tussock, low producing or native grasslands on Land Use Capability Classes VI and VII land. Because the topography of this land is generally not suitable for cultivation and often inaccessible by vehicle, control techniques are limited.

Matagouri is generally controlled by burning. The Otago Catchment Board sees no soil conservation problem when normal winter burning practices are used to control matagouri. Consequently, the areas affected by matagouri are largely outside those areas for which burning permits are required.

Usually fewer than 40 permits are issued each year to burn approximately 11,000 hectares on which matagouri is present. Half of these permits are renewals from the previous year. This suggests that it is difficult to get the correct conditions to burn matagouri.

In 1973, condition and trend plots were established on Two Mile Station, St Bathans, to assess the effects of burning on matagouri. Results showed that the tall tussock cover, both before and after burn recovery, was sufficient to hide the shrubby matagouri component.

Alternative control techniques attempted in Otago include: cultivation, which removed matagouri on good sites; mowing, which has reduced plant size for a period but has not controlled growth; and selective or heavy grazing, using goats, cattle and sheep, with goats giving the greatest control.

Jonathan A. Keogh

Studies on developed hill country at Millers Flat, Central Otago have shown:

- bees pollinate matagouri and may be an important factor contributing to a viable seed set. It may be good management to place hives in matagouri-infested blocks after plants have flowered;
- plants recruit only a small number of individuals to the population. Mortality among seedlings is high; and,
- trailing branches on young plants may take root.

Spring burning
Spring burning is a management tool, not an end in itself. Very cold frosty weather dries out plants and a hot fire will result, a good fuel base is provided. Follow-up grazing requires special wether flocks, dry cattle or goats, which must be forced on to spring growth for five years following the spring burn.

Autumn burning
Autumn burning presents a severe risk of fire escape. Breaks must be provided. There is a lack of knowledge at present about the use of fire retardants. Little is known about the effects of hot summer fires on A horizons in soils. Frost heave and soil loss are other effects to be considered. Two main advantages of autumn burning appear to be:
(a) burning the plant when it is most susceptible to damage, and
(b) the opportunity for follow-up grazing in winter.

Goats
More research is required.

Slashing
This appears to be an expensive procedure and there are gaps in our knowledge on such matters as timing. Where it is possible, cultivation is a better option.

Chemicals
The use of chemicals should be considered only when the economics of the practice can be proved. It might be an option on land with a slope of more than 28^{O} and an erosion risk. More research is needed on the most effective and cheapest spray rates.
Chemical control is a viable option when restricted to high-producing land or for stock access.

Boards
Site-specific permits should be considered and permit conditions should be more strict so that correct procedures are carried out. A total integrated programme is required.

Matagouri bibliography

Janet L. Scott

The following is a review of the published references on matagouri up to 1983 carried out by Janet Scott (in 1982) as a contribution to a review of the burning policy by the North Canterbury Catchment Board.

The review is highly technical but will never-the-less be of general interest to those seeking a better understanding of one of the most misunderstood plants of the hill and high country.

Introduction

Matagouri (Discaria toumatou) is an important plant in the South Island, but one about which little detail is known. It is considered to cover 2.66% of the total farmable land of the South Island, but no firm opinion seems to exist as to its status as a weed.

This is a summary of the information found from a survey of the literature regarding matagouri.

Taxonomy

In 1844 M. Raoul, previously a surgeon on two French ships stationed at Akaroa, published a list of New Zealand plants, describing matagouri for the first time. The genera Discaria is not endemic and is supposed to be of the sub-antarctic element as there are 15 related species throughout the South Pacific. Evidence of matagouri dates from the Quaternary era (Knox, 1969) in New Zealand. Discaria means disc-bearing, referring to the flower's form. The species is endemic, but very similar to the Australian D. australis. The name is a corrupted form of the Maori 'tumatakuru' (meaning 'tattoo-needle'), as is the name matagouri. The plant is also known as 'Wild Irishman' (Allan, 1967).

Description of plant

The plant is a semi-divaricating tree or shrub, up to 5 m tall and 30 cm diameter described as 'old man matagouri' (Cochane, 1927) (in calm, moist areas) but more usually around 1-1.5 m in a juvenile stage as 'creeping matagouri' (Daly, 1967). The plant can live for up to 150 years and the tree form takes 20 to 30 years to develop on good ground. Plants are easy to date by stem and root ring counts (Daly, 1969).

Xerophytic characteristics

Xerophytic characteristics, such as spines, thick cuticles and hairs, allow plants to live in extremely dry environments. Many of the plant's characteristics have developed in response to its environment rather than as protection from browsing (Cockayne, 1905, 1912).

However, more recent work suggests that moa-browsing may have induced or modified the xerophytic characteristics as many native divaricates seem to prefer wet conditions. Matagouri spines, like those of its overseas relatives, more probably reflect a xerophytic environment as moas could not feel spines on their horny face-plates (Greenwood and Atkinson, 1977).

Matagouri exhibits the following characteristics:

- the secondary, lateral branches are usually spined to reduce the transpirational surface, as is the cylindrical stem and brown colour of older branches;
- dwarfed and cushion forms protect against desiccation;
- rigid, interlacing branches protect against snow;
- limited light leads to shortened leaf-bearing branches;
- tannin in hypodermis protects against desiccation;
- sclerenchyma strengthens the deep tap root;
- perennial deciduous habit with small, leathery leaves;
- much bark and cork;
- well-developed annual rings;
- sunken stomata on under side of leaf only and stomata on stem;
- thick cuticle on all outer walls and special cutinised protection around guard cells;
- protected chlorenchyma in stem and leaves. All mesophyll cells contain chlorophyll and all plastids are small;
- water storage cells found below the vascular tissue of the leaf. The leaf epidermal cells, stem hypodermal and perhaps some nodules (Oldridge, 1922) also store water, but storage tissue is not abundant;
- the root grows first, then the shoot so securing a water supply (Cockayne, 1899).

Leaf characteristics

The leaves are 1.2-3 cm long and 0.3-0.6 cm wide. They are linear to narrow - obovate, obtuse and coriaceous with an entire margin. The leaves are fascicled or, more usually, opposite. They are usually glossy above.

Spineless form

Several spineless and semi-spineless plants have been described at Lake Wakatipu (Cockayne, 1922), New Brighton (Wall, 1922), and other places. Cockayne (1899) noticed that the shoots were leafy at first but soon, within a season (Daly, 1967) developed spines. Once spines are formed, they are not lost (Richards, 1956). The occurrence of spines is believed to be related to the plant's normally dry habitat (Cockayne, 1905; Cockayne and Allen, 1926).

Nitrogen-fixing ability

Matagouri is known to be nodulated and to fix nitrogen. Morrison and Harris (1958, 1959) found that all plants examined from various South Island localities had nodules. These nodules were morphologically similar to those of Coriaria spp. and seem to be infected with the same filamentous endophyte. Coriaria spp. were shown to be able to fix sufficient atmospheric nitrogen for all their needs, but matagouri needs some added nitrogen for growth. The amount of nitrogen fixed is enough to sustain it on the poor soils on which it grows (Morrison, 1961). Matagouri between 25 and 110 years old can fix up to 67 kg/ha per year of atmospheric nitrogen, a higher rate than gorse or broom (Daly, 1969).

Reproductive biology

Flower form

Matagouri flowers are produced either singly or in clusters and the three-lobed ovary rests on a disc. There are four to five greenish to clear white reflexed sepals and no petals. The flower is 3-5 mm in diameter (Allan, 1961; Daly, 1969; Primack, 1980).

Time of flowering

Matagouri flowers in spring and early summer and the flowers last one to five days, three on average. The flowers have a strong, pleasant fragrance. Several observers concluded that the plant is insect-pollinated (e.g. Thompson, 1880; Primack, 1980) as it has much pollen and nectar and has a strong smell. The pale yellow pollen and greenish nectar are produced in quantity and are good sources for bees (Walsh, 1967) as matagouri is one of the few plants flowering at such a time and place.

The peak flowering date is poorly correlated with duration of flowering, number of flowers per plant and number of seeds per capsule for the past or present year. All of the above factors are very variable from year to year within a population. Little variation was seen for any species difference from year to year but there are considerable changes for different altitudes and climates (Primack, 1980).

Gender, breeding, dispersal

Distribution of gender, outbreeding mechanism, implications for dispersal

The matagouri flower can alter its gender ratio. There appears to be a graduation between a totally male and predominately female plant. The ratio varies from year to year but all plants seem to have a similar gender strategy for one year. The variation appears to be influenced by the environmental conditions and amount of fruit set the previous year and not the overall status of the plant (Primack and Lloyd, 1980). Matagouri's reproductive biology encourages outbreeding. The flowers are self-sterile (Primack, 1979) and the stamens ripen before the stigma (Thomson, 1880).

A fruit containing more than one seed is a unit of long distance dispersal for this plant, especially as a full, unopened capsule can float for at least a week (Primack, 1979). Normal dispersal is through the explosion of the capsule (Daly, 1969; Primack, 1979).

Fruit and seed

The fruit is a dry, leathery capsule with three deep lobes and three locules around 5 mm in diameter (Allan, 1961). The fruit contains an average of 1.7 seeds (standard deviation = 0.2) only (Primack, 1980). This is only a fraction (7%) of the flowers pollinated. Insect inactivity in a cool spring also limits set, as the flowers are self-sterile (Lloyd et al., 1980).

Germination and growth

The black-brown seeds have a tough testa and usually are expelled from the capsule in late summer. Eighty percent of the fresh seed is dormant until they have had at least several weeks of cold and moist weather (to simulate winter). Viability may not be high as no seeds germinated in a trial at Lincoln (Spence, 1981). Most seeds germinate in late September and October and may do so in thousands around a mature plant. Few survive the first summer drought or competition. Best survival is seen on gravel of riverbeds, fans, eroding soils and on overgrazed grassland (Daly, 1967, 1969). The young plants are reported to be easy to transplant (Richards, 1956).

Physiographic distribution and ecology

Soil associations

Matagouri is able to grow on a variety of soils but prefers young and/or rich soils (Petrie, 1875; Cockayne, 1920; Daly, 1967), possibly for the higher calcium-bound phosphate levels (Daly, 1967; Cutler, 1977) and especially where there is an adequate water supply (Daly, 1967). In North Canterbury these are usually the yellow-grey earths.

Some plants are found on recent soils (e.g. Tasman). Matagouri also grows well on some of the more leached and weathered yellow-brown earths as they usually contain fresh coarse gravel or rock particles (Cutler, 1977; M.W.D., 1982).

Slope and erosion

In North Canterbury, most of the matagouri seems to be on slopes steeper than 20^{o} (M.W.D., 1982). This is due more to man's interference than to natural distribution (Ralph, 1958; Molloy, 1969), Most of the ground matagouri grows on has a slight to moderate erosion risk (M.W.D., 1982). Matagouri is a secondary coloniser, and hence any land it grows on has already been stabilised to some extent (Burrows, 1977b). Its deep taproot and extensive lateral rooting are also important in preventing erosion on erosion-prone areas (Daly, 1969).

Land forms

Matagouri can grow on a wide variety of soils and sites. However, it is adapted to an early successional phase. In the North Island, for example, it is usually found on sand dunes, coastal rocks and old terraces (Elder, 1966). In the South Island it is usually found growing below 1200 m and in sub-alpine to montane tussock and shrub succession communities (Wilson, 1976). Old stream courses, outwash terraces, talus fans, hillside gullies and depleted tussock land are usual sites (Cockayne and Foreraker, 1915; Barker, 1953; Connor, 1965; Wilson, 1976). It prefers sunny, well drained slopes (Barker, 1953; Cuff, 1982).

Vegetation association and successions

Matagouri is most common in short tussock and depleted or native grassland associations (M.W.D, 1982; Wilson, 1976). It is less vigorous on these sites, probably as these older soils are less fertile (Dobson and Burrows, 1977). It is a secondary coloniser on riverbeds, hillsides and stabilised scree slopes (Sheppard, 1965; Burrows, 1977a). It is not tolerant of shade and it can fill some of its own nitrogen requirements (Oldridge, 1922; Dobson and Burrows, 1977). Matagouri follows Raoulia and other first colonisers (Burrows, 1977b) but may be replaced by a tussock grassland (Calder, 1961). Matagouri harbours many plants within its shelter and nitrogen-fixing ability and so helps other plants to infiltrate burnt or depleted areas (Daly, 1967; MacMillan, 1979). It is a common successional phase after burning of grassland or scrub within its range of natural distribution (Zotov, 1939; Molloy, 1960). Matagouri is parasitised by Kerthalsella lindsayii var. clavata on Castle Hill.

Geographic distribution

Matagouri grows on coastal dunes in the North Island, south of Port Waikato on the west coast (T.G.M.L.I., 1961; Cockayne, 1971) and south of Hawkes Bay on the east coast. Some scattered bushes are found inland on old volcanic terraces (T.G.M.L.I., 1961; Elder, 1967; Daly, 1969).

In the South Island, it is distributed over approximately 3.3 million hectares from sea level to 1200 m (Daly, 1969), mostly on the eastern side. It is a dominant species over much open country (Hayward, 1967; Daly, 1969; Greenwood and Atkinson, 1977).

A few stands of matagouri trees exist in Nelson and on the West Coast (Cockayne, 1967). There has also been one bush recorded on the Chatham Islands (D.S.I.R., C.H.R. Herbarium). Matagouri was very common on the Canterbury Plains (Crawford, 1949; Hayward, 1967) and still covers 200,000 hectares of land in North Canterbury to some degree (M.W.D., 1982). It is the most extensive scrub-weed in Canterbury and Otago, but is not prominent in Nelson or Southland (Bascand and Jowett, 1981).

Agricultural significance of matagouri

Opinions vary greatly among farmers and others as to the seriousness of matagouri as a weed (T.G.M.L.I., 1961). Several advantages and disadvantages of this plant are mentioned below.

Matagouri as a useful plant

Matagouri is a very useful erosion-preventing plant, as it is able to colonise and stabilise shingle fans, riverbeds and unstable rock and shingle slopes (Daly, 1969; Dingwall, 1969). It has a deep taproot which may penetrate three metres or more into subsoil and rock and crevices (Daly, 1967) and has extensive lateral roots (Dingwall, 1965). Nitrogen fixed by matagouri helps stimulate adjacent plant growth and revegetation of bared surfaces.

Vegetation is encouraged, as are stock, by the cover afforded by matagouri (Dingwall, 1965). The Rainbow Station stock over-winter under matagouri to some extent (Simpson, 1979) and it provides shelter and nesting sites for many bird species (Dingwall, 1965; Simpson, 1979). Matagouri also gives shade for stock in summer and the sheltered sward below the plant is an emergency stock food and a source of

grass seed for the pasture. Matagouri also breaks up snowdrifts and so protects animals and pasture (Cuff, 1982).

Maori and pioneer uses

The Maori name for matagouri 'tumatakuru' means 'tattoo needle'. The older, dry spines were used for tattooing when no better needles, bone or stone, were available (Laing and Blackwell, 1956; Richards, 1956). Branches were interlaced in harrow cross-bars for brush-harrowing (Crawford, 1949). Matagouri wood was used as a building material when no other wood was available (Kirk, 1889) and for stock-whip handles (Potts and Gray, 1870). The wood has a pleasing grain and is good for turning as it is hard, dense and has close growth rings. It is however inclined to warp and develop cracks while seasoning (T.G.M.L.I., 1962).

Honey production

Matagouri honey was known in 1880 (Thomson, 1880), and matagouri is still an important early pollen and nectar source, although it is both a spring and summer producer. Both pale yellow pollen and greenish nectar are produced in some quantity. The resulting honey is a medium amber colour and has a mild flavour, suitable for the New Zealand palate (Walsh, 1967).

Matagouri as a weed

The main disadvantage associated with matagouri is the area it occupies (Leonard, 1962; Daly, 1969). A postal scrub-weed survey of South Island farmers showed that matagouri was common/widespread in 42% of farming land, occasional in 27%, a minor nuisance in 33% and a major nuisance in 11% of farming land (after Bascand and Jowett, 1979).

A quantitative scrub-weed survey of farmable land in the South Island by the Ministry of Agriculture and Fisheries showed matagouri was the weed which covered the second greatest amount of total ground (2.66%) - after bracken (2.85%). The greatest provincial land area covered by a single scrub-weed species was matagouri in Canterbury - the next being matagouri in Otago. Results for matagouri were as follows:

Area	% cover on farmable land	Estimated (km^2)	% cover on site	
			Sparse	Abundant
Canterbury	3.51 (0.19)*	795	24.24 (1.90)*	5.02 (0.83)*
Marlborough	2.14 (0.13)	105	36.86 (4.68)	2.80 (1.25)
Nelson	N	N	1.62 (0.57)	N
Otago	2.66 (0.18)	606	27.23 (2.14)	2.93 (0.69)
Southland	2.25 (0.21)	249	14.93 (2.01)	3.42 (0.98)
Westland	N	N	N	N
South Island	2.66 (0.10)	1756	23.06 (1.16)	3.52 (0.42)

* Standard Deviations N Negligible
(after Bascand & Jowett, 1981)

This infestation affects a farm in several ways. Sheep especially, find matagouri hard to walk through with the more stunted stands being the most difficult to traverse. Total grazing area is reduced, the twigs and spines down-grade wool, and very weak animals may die, entangled in the scrub (Dingwall, 1965). There is difficulty mustering such areas and Starvation Hill was perhaps named when sheep had to be taken off it with poisoned wounds on their noses from matagouri prickles (Gillespie, 1953). Burning of such areas may encourage erosion.

Thick patches of matagouri on lower, better country leads to greater grazing pressure on higher, more erosion-prone slopes. As matagouri responds well to fertilisers, it is predominantly a weed on properties being developed (Cuff, 1982).

Mature scrub can open up or be opened up by cattle, so sheep can graze underneath (Hughes et al., 1972; Dobson and Burrows, 1977).

The range of matagouri is similar to several other weeds and it is often associated with these, especially sweet brier, Rubus spp., gorse, broom and manuka. Sweet brier and Rubus spp. seeds may be introduced into a stand by the birds it harbours (Schofied, 1954; Dingwall, 1965), and matagouri can also harbour nassella tussock (Leech, 1981a).

Matagouri shelters rabbits. Rabbits had been noticed infesting areas (1910-1920), after having first made a warren in a matagouri thicket (Cockayne, 1919). Rabbits are still living in some thickets (Carnahan, 1957) and seem to eat new shoots and keep the plant in check. A great increase in growth of the weed was noticed when rabbits were brought under control (Schofield, 1954; Cockayne, 1969; Daly, 1969).

Rate of spread

The rate of spread of matagouri varies from place to place, depending on the recent history of the site, bird population to spread seeds (Moore, 1976), and climate. After rabbits had been brought under control, matagouri increased in numbers and size of bush because previously rabbits had fed on the young shoots and burrowed underneath the bushes (Cockayne, 1919b; Schofield, 1954; Daly, 1969). When starving they would often browse matagouri bushes (McCaskill, 1969).

It also spreads into grasslands depleted by fire or grazing, especially when previously burnt land is fertilised and not re-burnt (Leonard, 1962; Connor, 1965). The original range of matagouri seems to have been reduced (Ralph, 1958), but it appears to be holding its own now (Daly, 1969).

Matagouri is intolerant of shade (Daly, 1969) and, as it is relatively slow growing, is sensitive to competition (Molloy, 1969). A dense sward will suppress seedlings (Daly, 1969; Dobson and Burrows, 1977), but it responds well to any pasture improvement, especially fertiliser application, and may even form a dense thicket (Matthews, 1980). Low available phosphate, insufficient root aeration and competition for light and moisture from surrounding vegetation may contribute to the absence of matagouri on a site (Daly, 1967), while the wider growth rings after rabbits had been controlled shows the effect of this pest in limiting the spread of matagouri (Moore, 1976).

Response to fertilisers

Matagouri usually grows on younger soils (Knox, 1969) where there is a high soil phosphate level (Burrows, 1976), and it can only invade and increase in depleted vegetation and soil (Leonard, 1962; Connor, 1965) where the sward is not too thick. It responds very well to both sulphur and phosphate and hence to superphosphate. It does not become more palatable and can cover previously clear grassland, when grass competition is reduced (Dingwall, 1965; Daly, 1969; Cuff, 1982). Thus, land development can directly lead to the problem of matagouri as a weed (Cuff, 1982).

Control of matagouri

Control by fire

One of the reasons for the spread of matagouri is considered to be the reduction of extensive burning and the subsequent spread of matagouri into the depleted areas (Leonard, 1962). Despite the fact that burning leads to erosion (Cuff, 1982) and a risk of fire spread (Dingwall, 1965), farmers seem to prefer burning matagouri areas, probably because it is a cheap and convenient method of suppressing a large area (T.G.M.L.I., 1962). Matagouri is also considered one of the most

fire-resistant plants in New Zealand. Although not truly resistant, it regrows rapidly following burning. It is a member of one of the usual plant successional stages after a burn in the Canterbury foothills (Molloy, 1960, 1969; Wilson, 1976). It is not surprising, therefore, that burning rarely kills matagouri completely.

Time of burning is very important. Spring burning would have to be repeated every five to seven years with no guarantee of success, as only the top growth is killed and new shoots appear within two months (Dingwall, 1965). A very hot fire in spring or summer may burn all top growth, but some larger plants always survive to provide a seed source (Daly, 1967, 1969) and the roots survive most fires to regrow (Burrows, 1977a). The claim that the roots are frequently 20 or more years older than the top of the plant is supported by annual ring counts (Daly, 1969).

Winter burning merely increases the number of stems per plant when the plant starts growing again in the spring. Five years after such a burn, the effective grazing area can be reduced to 40-50% of the original area (Daly, 1969).

Burning followed by crushing and cultivation may work for some areas (Dingwall, 1965). A quick, hot fire in the growing season, followed by grazing at more than 10-12 stock units per hectare seemed to kill all regrowing plants after four and one half to five years in one trial in South Canterbury. However, this control is only possible on an intensively grazed property (Cuff, 1982), as less intense grazing merely causes continual production of basal shoots (Daly, 1967).

Oversowing and topdressing are necessary after such a burn on this country. If these operations are done before burning, the green vegetation is more difficult to burn (Symons, 1956). Cutting of matagouri by hand or machine gives a similar regrowth response (Dingwall, 1965; Cuff, 1982).

Control by chemicals

Chemical control is costly and very dependent on the time of application and on the concentration used (Cuff, 1982). Several trials have measured the response of matagouri to organic herbicides. Matagouri was shown to be susceptible to 2,4,5-T. and Tordon, and their derivatives (Leonard, 1962, 1965; Daly, 1967).

All chemicals tested only worked at high concentrations, probably due to the small leaf area of the plant. The deciduous habit of matagouri forces any spraying to be done from spring to mid-summer (Cuff, 1982) and really only when the plant is flowering, to guarantee full leaf (Bell, 1982, pers. comm.; Daly, 1982, pers. comm.). Dingwall (1965), Leonard (1962, 1965) and Daly (1967, 1969) found that heavy applications, to saturation, of the above chemicals gave satisfactory kills while weaker concentrations merely killed the top growth; heavy concentrations being more than four kilograms per hectare active ingredient. High pressure spray equipment (414 kPa) is needed to obtain a satisfactory application rate on the plant (Dingwall, 1965).

Matthews (1980) regards 2,4,5-T. with dieselene, at a concentration of 1:160, as giving far better results than 2,4,5-T. This is to be applied as a basal application when soil moisture levels are high (see M.W.D. Technical Bulletin No. 216, 1967). Picloram - 2,4,5-T. mixture (Tordon) could be useful as an overall spray when the plant is in full leaf and soil moisture levels are high. However, picloram is very toxic to clovers and a pasture can take well over a year to recover (Matthews, 1980; Cuff, 1982). Picloram-tricolorpyr or only tricolorpyr could be used (Bell, 1982, pers. comm.).

One farmer's trial showed that 2.8 l/ha of Tordon gave a 40% kill, while both 11 and 22 l/ha gave 98% kills. This is however a large and expensive amount of chemical (Leech, 1981b) and possibly

only small pockets of matagouri could support this cost (Cuff, 1982). The 11 l/ha application rate may be adequate treatment for many areas (Bell, 1972, pers. comm.).

The most extensive trials since Dingwall's (1965) were carried out by the South Canterbury Catchment Board. Several formulations of Tordon were used at several concentrations. After five years, a trial on mature matagouri showed that Tordon granules applied at 168 kg/ha (3.3 kg/ha a.i.) in September was the best treatment for that time. For later dates, (November and December) Tordon was found to be more effective at a 1:200 dilution rate. A stronger solution (1:100) gave only slightly better results.

The second trial was designed to examine the effect of three formulations of Tordon Brushkiller. Analysis after only three months indicated that there was a better kill in tall, oversown and topdressed (O.S.T.D.) matagouri than in low stands. For low matagouri, the 50D form is the best at low application rates, but 52O and 52O diesel were far better as the concentration was increased. 52O and diesel, applied in December, was found to be the best treatment and the only satisfactory one for this stand at Mt Possession Station. A stand of tall, O.S.T.D. matagouri in a block next to the low stand was also treated. Both 52O and 52O diesel were better treatments than 50D, the proportion killed was more than in the low stand. No increase in efficiency was noted with the increased concentration. Other trials have seen kill rates go down with time so the above results are still only indications of the final results.

Control by stock and other animals

Matagouri attracts bees and flies (both native and introduced) which pollinate its flowers. It is also eaten, or roosted on, by many green, cockchafer beetles (Scarabaeidae) in the Mount Cook National Park area (Wilson, 1976). The larvae of Gastrosarus nigricollis are also reported to eat matagouri. They kill tips and hollow out twigs (Milligan, 1975).

Stock will also eat matagouri, but only the young shoots. In most cases, this extensive grazing together with burning merely causes the production of more basal shoots and a thick basal crown. Periodic burning and grazing will maintain a matagouri population indefinitely (Daly, 1967, 1969), however, cessation of both burning and grazing may induce greater height, and lower establishment rates with no difference in survival rates of established plants (Primack, 1978).

Matagouri scrub will open up as it matures to allow sheep to graze beneath it (Dobson and Burrows, 1977). The low establishment rates reflect the competition of the vigorous grass sward which suppresses seedlings (Daly, 1969).

To reduce matagouri, a combination of both cattle and sheep is needed. Cattle tracking may open up areas for sheep (Hughes et al., 1971). Cattle, and sometimes sheep, will graze fresh, spineless shoots once most of the plant is broken down by fire, machine flailing or trampling, (Daly, 1969). This requires very heavy stocking rates - a Lincoln trial indicated up to 100 stock units per hectare, but usually far less on small blocks (Daly, 1969). Subsequent work has indicated that 10 to 12 stock units per hectare on a small block can kill matagouri regrowth from burning within four and a half to five years. Fire, then herbicide, then grazing, also killed the plants within five years. In this case the herbicide had very little effect as there seemed to be too few leaves on which to act (Cuff, 1982).

Practical control - a summary

- for effective control, intensive measures are needed
- no single method will work with any real degree of success despite any preference for burning
- burning followed by a herbicide

spraying of regrowth may work, especially if the area is oversown and topdressed after the spray (Dingwall, 1965)
- Daly (1969) recommended burning, oversowing and topdressing followed by periodic hard grazing, 50 to 100 s.u. per hectare, of small blocks
- intensive grazing of small blocks is necessary to keep matagouri suppressed and to eventually kill it
- 10 to 12 s.u. per hectare seems sufficient to kill matagouri after burning in the South Canterbury foothills
- herbicides are too costly at present for controlling matagouri on the poorer quality land on which it grows (Cuff, 1969, 1982).

Conclusions

Matagouri is a common plant but little is known of its importance to agriculture.

- It has many effects on farming in the South Island, ranging from providing an early pollen and nectar source for bees to harbouring dodder, sweet brier, nassella tussock and rabbits.
- It is an important member of the early shrub colonisation phase and is of importance in erosion-prone areas as it has a deep taproot and is xerophytic.
- It is impenetrable to sheep when young or when stunted by burning. Its presence on lower grazing land tends to force stock onto higher, more erosion-prone lands.
- It is a nitrogen-fixer and so helps to build up the nitrogen content of soils aiding both matagouri and surrounding plant growth.
- Its rate of spread is not well known but a recent scrub-weed survey (Bascand and Jowett, 1981) will provide a baseline for future work.
- No simple control measure is known. Heavy, expensive chemical applications when the plant is in full flower provide some control. Fire merely produces more basal shoots unless accompanied by suitable follow-up treatment. One of the cheapest and most effective methods proposed is to burn and graze heavily for about five years. However, additional fencing would be necessary to facilitate the stocking intensity needed. An additional problem is that matagouri is most vulnerable to grazing pressure in the autumn, when sheep need good grazing to put on condition for the winter.
- The value of much of the land covered by matagouri may not justify the expense of intensive control measures.

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A general description is given of the catchment's characteristics and history; and recommendations for future use.

Hooker, J.D. 1867: Handbook of the New Zealand flora. Reeve and Co., London. pp. 43-44.
A short description is given for all known genera and species.

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Results of grazing cattle on tussock land are given, including the effect seen on matagouri on such areas.

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A brief description of matagouri and some of its uses are given in this general account of the New Zealand flora.

Knox, G.A. (ed.) 1969: The natural history of Canterbury. A.H. and A.W. Reed, Wellington. 620p.
A general description is given of the area, plants, geology, history and climate. (Includes Burrows, C.J., Lowland and upland scrub; and Harris, W.F., Quaternary history of the vegetation.) See also Molloy, B.P.J. 1969.

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An article on the progress of the Nassella Tussock Board's work; matagouri harbours this weed in some areas.

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A description of a South Canterbury farm's development, which describes a trial on chemical control of matagouri.

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A description of the major scrubweeds of New Zealand, useful control measures and spread of these weeds.

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A comparison of various New Zealand native plants' reproductive biologies - one plant being matagouri.

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A history of the Molesworth, Rainbow and Tarndale Stations - describing the vegetation on them and the influence of farming and the rabbit infestation on the properties.

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An account of the distribution and associations of plants in this area.

Martin, W. 1947: The flora of New Zealand. 3rd ed. Whitcombe and Tombs Ltd., Christchurch. 266p.
A very general account of New Zealand flora - mainly of trees and shrubs.

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A very brief description of the worst weeds of New Zealand.

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A description of control methods for the more common weeds of New Zealand - including matagouri; for which not much is known.

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A general description of each plant is given; with a description of its wood anatomy and up to seven electron micrographs of its wood structure.

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A brief account of some of the native and introduced wood-boring insects and their food.

Ministry of Works and Development 1982: Land Resource Inventory.
Printouts from a computer search of their matagouri data. An analysis of the North Canterbury region for areas containing matagouri; tabulated by slope, soil set, vegetation and erosion risk. See printouts for details.

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Moore, L.B. 1955: The plants of tussock grassland. Proceedings of the New Zealand Ecological Society 7: 7-8.
A description of the common plants and their habitats is given.

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A brief description is given of the more common plants of the coast, most with a small sketch in black and white.

Moore, L.B. 1976: The changing vegetation of Molesworth Station, New Zealand. 1944-1971. D.S.I.R. Bulletin No. 217. 118p.
An account of the changes in the station over a period of 25 years.

Moore, L.B.; Irwin, J.B. 1978: The Oxford book of New Zealand plants. p.88.
A brief and concise description of the genus and species; with a half-tone drawing of a twig and dissected flower.

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All plants studied so far have root nodules infected with some fungus or fungi believed to fix atmospheric nitrogen.

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All matagouri and Coriaria plants examined to date have root nodules and the nodules are similar morphologically.

Morrison, T.M. 1961: Fixation of nitrogen-15 by excised nodules of Discaria toumatou. Nature 189: 954.
Experimental results show that matagouri can fix atmospheric nitrogen.

Natusch, S. 1975: Matagouri. New Zealand's Nature Heritage Vol.6, No. 76: 2124-2125.
A very brief description of the plant and its life history.

Oldridge, D.M. 1922: Plant succession on shingle fans. Unpubl. M.Sc. thesis, University of Canterbury, Christchurch. 186p.
A description, of the habitat and plants of this area, which discusses the morphology and associations of matagouri in some detail.

Orwin, J. 1974: Annotated bibliography on the ecology of New Zealand indigenous scrub, 1929-1970. New Zealand Journal of Botany 12: 45-113.
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Petrie, D. 1895: List of the flowering plants indigenous to Otago, with indications of their distribution and range in altitude. Transactions and Proceedings of the New Zealand Institute 28: 540-591.
A check-list of the common plants of this area, with brief comments on their usual habitats.

Poole, A.L.; Adams, N.A. 1963: Trees and shrubs of New Zealand. Govt. Printer, Wellington. 257p.
A description, and black and white drawing, is given for most native trees and shrubs.

Potts, T.W.; Gray, W. 1870: On the cultivation of some species of native trees and shrubs. Transactions and Proceedings of the New Zealand Institute 3: 181-202.
A description of some native plants suitable for cultivation; including a description of matagouri.

Primack, R.B. 1978: Effects of grazing on indigenous shrubs in tussock grassland at Cass, Canterbury, New Zealand. New Zealand Journal of Botany 16: 461-469.
Results are given of a trial to determine the effects of spelling tussock pasture, by comparing enclosure and control plots for growth and species occurrence after 17 years.

Primack, R.B. 1979: Reproductive biology of Discaria toumatou (Rhamnaceae). New Zealand Journal of

Botany 17: 9-13.
A description of the matagouri flower, the insects which pollinate it and its strategies and methods of seed dispersal.

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The results of a study into the flowering time and seed production of three native shrubs - they show great variation in their strategies.

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The results of a study into the proportions of the genders in Leptospermum and matagouri flowers are given. Matagouri usually has an hermaphroditic flower, but the amount of pollen or functional ovaries varies each year.

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The type and type locality (Akaroa) are described. The type plant is held in the Herbarium of the Museum National d'Histoire Naturelle, Paris.

Relph, D.H. 1958: A century of human influence on high country vegetation. New Zealand Geographer 14: 131-146.
A summary of the effects man has had after 100 years on Castle Hill. Cattle have been named as the reducing factor for matagouri in the area.

Richards, R.C. 1956: Our New Zealand trees and flowers. Simpson and Williams Ltd, Christchurch. 297p.
Descriptions of various native plants' appearance, habitat and life history. Matagouri is included.

Salmon, J.T. 1968: Field guide to the alpine plants of New Zealand. A.H. and A.W. Reed, Wellington. pp. 122-123.
A very short description is given for the more common alpine plants.

Salmon, J.T. 1980: New Zealand flowers and plants in colour. 2nd ed. 235p.
A small colour illustration and description is given for many plants, including matagouri.

Schofield, R.C. 1954: Scrubweed of Central Otago. Proceedings of the Seventh New Zealand Weed Control Conference 7: 86-88.
A description is given of the worst weeds of this area, including matagouri.

Scott, G.R. 1968: The root nodules Streptomyces of Coriaria arbores and Discaria toumatou. Unpubl. M.Sc. thesis. University of Canterbury, Christchurch. 164p.
A description is given of the anatomy and physiology of the nodules and their endophytes. Both plants are shown able to fix atmospheric nitrogen through these nodules.

Sheppard, J.S. 1965: The role of Cassinia fulvida R.Br. in the succession of scrub at Cass, Canterbury. Unpubl. M.Sc. thesis. University of Canterbury, Christchurch. 140p.
The role of matagouri is considered briefly within this study.

Simpson, P.G. 1979 (ed.): Wairau mountain lands. Marlborough Catchment and Regional Water Board and the National Water and Soil Conservation Board. 189p.
A survey of the characteristics, including the vegetation, of the area.

Spence, C.B. 1981: Germination of matagouri (Discaria toumatou) from seed. Unpubl. project, Diploma of Field Technology. Lincoln College, Canterbury. 36p.
The results are given for a trial on the germination mechanisms of matagouri seed - none germinated.

Symons, J.L. 1956: Weed problems in South Canterbury. Proceedings of the

Ninth New Zealand Weed Control Conference 9: 7-12.
A description of weeds in South Canterbury , including matagouri.

Thomson, G.M. 1880: On the fertilisation etc. of New Zealand flowering plants. Transactions and Proceedings of the New Zealand Institute 13: 241-288.
A detailed account of the fertilisation strategies of some New Zealand plants - with a short reference to matagouri.

Tussock Grasslands and Mountain Lands Review, 1961: No. 1, pp. 9-11.
A description is given of matagouri to provoke some discussion for a later publication.

Tussock Grasslands and Mountain Lands Review, 1962: No. 2, pp. 20-21.
The opinions of some farmers who replied to the first description and call for further information are given - outlining some of the advantages and disadvantages of matagouri on their properties.

Wall, A. 1922: The botany of Christchurch. Lyttelton Times Co. Ltd, Christchurch. 41p.
A brief, general description of the major plant associations and rare plants near Christchurch.

Walsh, R.S. 1967: Handbook of New Zealand nectar and pollen sources. National Bee-keepers Association of New Zealand Inc. 55p.
A description is given of most native bee-pollinated flowers, their distribution, flowering time, nectar, pollen and resulting honey.

Williams, P.A 1981: Bibliography and subject index for Leptospermum ericoides and L. scoparium (Myrtaceae) in New Zealand, 1889-1980. New Zealand Journal of Botany 19: 305-310.
Reference.

Wilson, H.D. 1976: Vegetation of Mount Cook National Park, New Zealand. National Parks Authority No. 1 Scientific Series. Wellington. 138p.
A well-presented description of the plants and characteristics of the National Park. Associations, successions and influence of animals are discussed.

Wilson, H.D. 1978: Field guide; Wild plants of Mount Cook National Park. Field Guide Publications, Christchurch. 294p.
Descriptions are given for most plants of this area, both native and introduced, with a description of their name, habitat and a small illustration - the text is brief.

Zotov, V.D. 1939: Survey of the tussock-grasslands of the South Island, New Zealand. D.S.I.R. Bulletin No. 73. (also in New Zealand Journal of Science and Technology 20A: 212-244.
A brief overview of the tussock grasslands' history, distribution and plant associations, mentioning matagouri briefly.

Rewards

Jim Morris

The winter snows and summer sun
Look on a small back country run.
Where man is dwarfed by ridges high
And fog bound tops that pierce the sky
With rivers running swift and cold
And forests that are centuries old.

Where deer and chamois did abound
Before the choppers were around.
And salmon spawn in holes so deep
Beside which graze Merino sheep.
Paradise ducks spoil the calm
Crying as they fly from harm
And hares play in the dewy dawn
As sunrise brings another morn
And keas scream, as on the wing
They soar the world, as if its king.

But man intrudes to run his stock
And "make a go" of this rough block.
With puny efforts - some say in vain
Where he has tried this land to tame.
Though cash rewards are not immense
And there was need of many a fence,
And profits few and far between
You now can see where he has been.

But more than money and such things
Is satisfaction each day brings;
And feelings, that are hard to write
As one who loves the dark of night;
And safer feels in mountain storm
Than on a smooth suburban lawn.
The ranges vast are here to stay
And he's content to spend his day,
Working in their rugged grip
His recompense - the love of it.

A tribute to Lancecot W. McCaskill, C.B.E., D.Sc. (honoris causa)

John A. Hayward

Lance McCaskill, foundation director of the Tussock Grasslands and Mountain Lands Institute (TGMLI), died in August 1985. In his 85 years he combined four careers - teacher, conservationist, director, author. At one of his many successive "retirement" functions he dismissed the compliments with the remark "I just happened to be in the right place at the right time".

The fact is, that as an inspiring teacher his remarkable life was characterised by his being in the right place before the right time.

After graduating from Lincoln College with a Diploma and Bachelors degree in agriculture he began his teaching career in 1923 cycling to schools on the Hauraki Plains and Coromandel as a visiting teacher of agriculture and natural science. He persuaded teachers to make native plants a part of the nature study curriculum and gave away thousands of plants for home and farm planting from the nursery that he and J.D. McKay had established.

In 1927 and 1928 he taught agriculture at Timaru Boys' High School.

He lectured in Botany at the Dunedin Teachers' College and the Christchurch Training College before being appointed to Lincoln College in 1944. In all of these appointments he devoted himself with enthusiasm to bridging the gap between town and gown, farmer and scientist. He took a particular interest in participative education, taking part in such events as farmer-organised conferences, travelling schools and YFC meetings.

He became Grand Patron of the New Zealand Young Farmers' Clubs. In recognition of his tireless support the YFC established the L.W. McCaskill trophy for community service.

He organised lecture tours, field days, radio broadcasts and publications. Generations of students remember the small man with the commanding presence who had an obvious love for this land and whose teachings were centred on the theory and practice of conservation.

He was an original member of the Royal New Zealand Forest and Bird Society and lectured widely on the need for habitat protection. While at the Christchurch Training College he established a unique teaching garden of more than 400 species.

In the 1930s he carried out private studies of damage done to native plants by noxious animals. During this period he wrote many articles and spoke to many organisations in an attempt to gain public recognition for the problems of noxious animals and soil erosion.

In 1939, while at Christchurch Training College, he was awarded a Carnegie travelling scholarship to visit America and Canada to study rural education, soil conservation and nature conservation.

On his return he was appointed chairman of the Soil Conservation Committee of the Canterbury Progress League and was a tireless advocate for water and soil conservation legislation. At one stage of the parliamentary debate he showed his lantern slides in the Legislative Chamber so that members might understand the real character of the problem that they were addressing.

Between 1944 and 1960 he served on the North Canterbury Catchment Board, the Soil Conservation and Rivers Control Council and the New Zealand Catchment Authorities Executive.

In 1946 he introduced and taught the first university courses in soil conservation. When in 1973 he wrote the history of soil conservation in New Zealand, he donated the royalties to the Association of Soil Conservators.

His commitment to the conservation of flora is best known in his work to preserve the Castle Hill buttercup. In 1948 with the help of Lincoln College students, he fenced a reserve around the 32 remaining plants. With devotion and care he nurtured the surviving plants. Today they number more than 400.

He was active in preserving New Zealand's last remaining area of Pittosporum obcordatum in the Wairoa valley (Hawkes Bay). For many years he cared for the alpine garden at Arthurs Pass. In 1968 he fought with the Ministry of Works and the National Parks Authority to prevent the realignment of State highway 73 through the tarns at Arthurs Pass. He was a member of the Riccarton Bush Trust and has helped to establish native plants in that reserve.

His love of New Zealand's scenic and natural landscapes led to a direct involvement with our National Parks and reserves. He was an original member of the National Parks Authority and played a major part in developing that Authority's early policies. It was at Lance's instigation that the authority became a subscribed member of the International Union for the Conservation of Nature. He was convenor of the committee for ranger training and appointments. He was a member of the Arthurs Pass National Park Board and consultant to the Tourist Department for landscaping the grounds of the Hermitage, Mt Cook.

It was inevitable that his activities would lead to controversy and conflict, for while problems of land and water use depend on scientific understanding they also involve social, legal, and economic issues not normally considered by scientists. Lance enjoyed being at the centre of controversy. In fact some of his most significant accomplishments came from the storms created by his advocacy of a chosen cause or his criticisms of those with a vested interest in retaining the status quo.

He was impatient of procrastination and of what seemed to him to be the devious ways of some government departments and large organisations. He never hesitated to denounce those who sought to use public resources for selfish gain.

When TGMLI was established in 1960 it had the objective of bringing together the many aspects, disciplines, professions and systems of administration that are related to New Zealand's hill and high country. Lance was the natural person to develop and lead such an enterprise. His interests in agriculture, nature conservation, national parks and soil conservation gave him the ability to think integratively and to promote approaches to sustainable, multiple use.

In a period when many called for more science and more research, Lance recognised that the most serious deficiencies were not in science but were in the inadequate mechanisms for coupling available knowledge with existing problems. With his experience as a teacher and his specialist knowledge of rural extension he established a character for the Institute as an organisation that would bring together the knowledge from science and apply it to problems of land and water use.

What led this remarkable man to accept a Director's position at about the time most of his colleagues were contemplating retirement? Lance McCaskill never thought of himself as a "scientist". His was a skill and craft which is only now coming into renewed respect - holistic natural history, a kind relevant to and inclusive of people. At an Institute of Agricultural Science section meeting in Christchurch before the appointment of the first TGMLI Director, he and other candidates for the position outlined their particular interests - Lance's were all about people.

After his retirement in 1965 he surveyed and reported on 700 of New Zealand's scenic reserves. The Department of Lands and Survey published this work in 12 separate reports. He also wrote several books including "Molesworth" and "Hold this Land".

During his lifetime he received many awards and distinctions including:

Peter Scott Award for Conservation, from the International Union for the Conservation of Nature, 1984,

Honorary Life Membership, International Union for Conservation of Nature, 1981,

A Doctorate of Science (Honoris causa) from University of Canterbury at Lincoln College Centenary in 1978,

Companion of the Order British Empire CBE, 1969,

Fellow of Institute of Agricultural Sciences, 1966,

First honorary member NZ Association of Soil Conservators 1965,

Associate of Honour, Royal NZ Institute of Horticulture,

Loder Cup, Royal NZ Institute of Horticulture, 1952,

Bledisloe Medal, Lincoln College, 1944.

But beyond these awards and distinctions he was, for generations of New Zealanders, an inspiring teacher who shared generously his love for this land and its natural heritage.

John A Hayward

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Proceedings of the 1985 Hill and High Country Seminar, edited by B.T. Robertson and W. Johnston. **$11.00.**

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Review of Waitaki water resource management information edited by Janet D. Gough. This report was prepared for the Waitaki Catchment Commission and Regional Water Board, Kurow. It reviews present day use patterns of the waters of the Upper Waitaki and assess potential use under present day knowledge. The review will be used as a basis for developing strategies for managing that water resource. 1984. 83p. **$16.50.**

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Towards a resolution of conflict in water resource allocation, M.N. Anderson et. al. This discussion based on examination of the Rakaia River debate was completed by second-year M.Sc. (Resource Management) students. The aim of the study was to provide guidance for the Planning Tribunal in resolving conflicts in water resource allocation. 1984. 109p. **$14.74.**

A social-economic study of land development for farm settlement at Butler's by C.N. Taylor, A. Blake-Kelly and K.L. Leathers. This study was commissioned by the Commissioner of Crown Lands, Department of Lands and Survey, Hokitika. The primary aim of the study is to identify the likely impacts of publicly-funded programmes of land development for farm settlement on the social life and economy of small communities in the West Coast region. 1985. 121p. **$13.74.**

Conservation of transport fuel in New Zealand. A review and research recommendations for the Liquid Fuels Trust Board by Janice Wright. The report is in five sections concerning the transport of people, transport of goods and some options for the long term. It seeks to identify "oil fields" on the demand side of the transport sector. Prepared in 1984, published in 1986. 41p. $8.80.

CENTRE FOR RESOURCE MANAGEMENT INFORMATION PAPERS

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Phosphorus losses through transfer, soil erosion and runoff: process and implications by J.C. Ward, J.M. Talbot, T. Denne and M. Abrahamson. This report presents an examination of phosphorus losses from the production system and the attendant consequences on environmental quality. 43p. **$7.70.**

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The impact of recent Government policies on the economics of South Island hill and high country farming by I.G.C. Kerr and N.W. Taylor. 30p. **$6.60.**

OTHER PUBLICATIONS IN PRESS

Introduction to non-market valuation: Theory and methods by G.N. Kerr.

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The Contribution of **L.W. McCaskill** to the natural history of New Zealand is being commemorated in a number of ways. In his memory, Lincoln College is establishing a prestigious postgraduate scholarship in soil conservation, land management, National Park management, nature conservation or rural education and extension.

It is anticipated that this scholarship would be awarded annually for masterate or doctorate studies at Lincoln College or in appropriate cases, other universities.

In addition, Lincoln College will explore the possibilities of an annual lecture by the recipient of the Loder Cup (or some other suitable person) to senior school students at several locations throughout the country. The Loder Cup is awarded annually by the Minister of Agriculture to "...lovers of nature in New Zealand to encourage the protection and cultivation of the incomparable flora of the Dominion." and was awarded to Lance McCaskill in 1952.

Likewise the organisers of the Tussock Grasslands and Mountain Lands Hill and High Country Seminar for 1987 and subsequent years, will be encouraged to include topics reflective of L.W. McCaskill's interests.

To establish the scholarship a fund will need to be established and invested to sustain the cost of an annual award. A fund in excess of $30,000 would make this possible. Already $20,000 has been promised.

Contributions to the L.W. McCaskill Scholarship Fund are very welcome and you or an organisation you are associated with are invited to send a contribution to:

The Registrar
P O Box 94, Lincoln College, Canterbury.

Please find enclosed a contribution of $..... towards the L.W. McCaskill Scholarship Fund,

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Address:
_____
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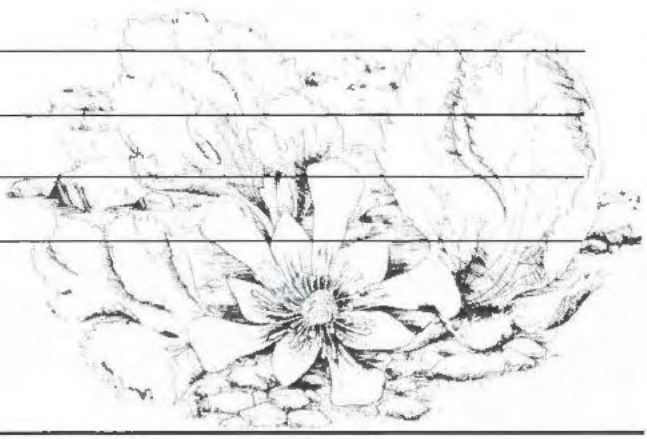

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Ranunculus crithmifolius