Vegetation History of the South Island High Country

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Summary

Project and Client

Landcare Research, Lincoln, prepared an article summarising key trends in and causes of vegetation change in the South Island high country, as background input to Crown Pastoral Lease tenure review, December 2003.

Objectives

Review, as a popular article, current understanding of the vegetation cover states and changes in the South Island high country, with relevance to pastoral leases, featuring:

- prehuman context of climate-induced change
- vegetation state at time of Māori arrival
- impact of Māori settlement (Pre-European (1850) vegetation state)
- impact of European settlement.

Method

Review based on published work. A brief bibliography of key publications is appended.

Main Findings

- The indigenous vegetation of the South Island high country is adapted to seasonal, often dry and fluctuating climates. Over the past 2.5 million years, environments have fluctuated between cool, dry windy glacials with virtually treeless grassland, shrubland and herbfields, and forested interglacials under mild climates. For the last 12 000 years, the South Island high country has been in an interglacial state, with lowland and lower montane areas largely in tall podocarp forest, and montane and subalpine regions in a variable cover of beech or montane podocarps and broadleaves, and above treeline subalpine scrub and tall tussock grassland. The driest areas of Central Otago and the Mackenzie Basin supported scrub conifers, small-leaved shrubland, kōwhai and kānuka, with grassland or herbfields on the driest soils. Mountain tōtara, silver beech and celery pine formed extensive forests on the wetter, higher slopes of mountains within these semi-arid regions and at their margins. Fire was rare in these prehuman ecosystems.
- Māori settlement in the 13th century was accompanied by devastating widespread fire, and within two centuries some 75% of the forest and tall scrub cover in the eastern South Island had been destroyed. In drier, eastern areas, and at low elevations, the destruction of tall forest was more or less complete, and in its place were tall tussock (which had migrated downslope from its alpine and subalpine habitat) and short tussock grasslands, scrub and fern and patchy, low forest. However, over much of the area now regarded as pure tussock grassland, a shrubland element was much more prominent.
- Occupation by European graziers led to a new cycle of fire designed to stimulate fresh palatable grass foliage and to open up scrubland for grazing. Palatable shrubs, native herbs and grasses reduced under high stocking rates of sheep and cyclical rabbit outbreaks. In many heavily grazed areas there was a decline in the stature, vigour and cover of the main tussock species. And finally, the pasture grasses and forbs, and dozens of aggressive weeds, began to dramatically alter the functioning of native plant communities.

Conclusion

- The South Island high country poses many problems for maintenance and enhancement of total indigenous biodiversity. From a strict biodiversity perspective, re-establishment or extension of indigenous woody biomes, similar to those of the past, would be ideal. However, many practical problems surround such a solution, including low fire resistance by native shrubs and trees, and their poor performance in regenerating in the presence of introduced pasture grasses and weeds. Many grassland areas have an almost complete lack of suitable natural seed sources due to loss of woody natives and absence of seed dispersers. Rather than following a strict blueprint based on the original vegetation cover, local solutions will be needed to maximise indigenous biodiversity.

1. Introduction

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2. Objectives

Review, as a popular article, current understanding of the vegetation cover states and changes in the South Island high country, with relevance to pastoral leases, featuring:

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3. Vegetation History of the South Island High Country

The South Island high country (and in particular, the pastoral leases and adjacent land) includes, but is not confined to, the driest, most drought-prone and seasonal climates in New Zealand. This near-continental-type climate in an otherwise oceanic, moist archipelago resulted in speciation of unusual plants and animals adapted to its extremes, and distinctive communities found nowhere else. A consequence of the dry climate has been an elevated susceptibility to fire, and less remains of the unmodified vegetation than anywhere else in the New Zealand high country.

3.1 Prehuman history – influence of glaciation and climate change

Between 5 and 2 million years ago the characteristic landscapes of southern New Zealand were formed during rapid tectonic uplift, which created the axial mountain chains. A sharp depression of mean annual temperatures associated with a global cooling about 2.5 million years ago built glaciers in the South Island mountains, and led to the expansion of grassland and shrublands and retreat of the previously dominant moist temperate forest cover. The period of fluctuating climates that this cooling initiated, and which persists through to the present, is called the Quaternary.

Quaternary climates have not been stable, undergoing marked cyclical fluctuations between warm and cold states. There have been about 50 of these warm-cold cycles during the last 2.5 million years. During this time New Zealand has overall been cooler than at present. Although warm, the interglacials (such as the one we are in now) have tended to be brief, lasting not much more than 10 000 years on average. The glacials are longer and cooler, culminating in brief periods of intense cold known as full-glacials. The Last Glacial entered its coolest phase (5–6^{o}C below present), the Last Glacial Maximum, around 30 000 years ago. Glaciers extended forward in a series of pulses between 26 000 and 19 000 years ago, building giant terminal moraines and deepening the South Island lake basins. Rainfall was much lower than at present, perhaps by more than a third, and the drier atmosphere greatly increased the severity of winter frosts. The expanded land area increased the seasonal temperature range in the eastern interior, summers being warmer and winters colder than would be predicted from annual temperatures. Loess sheets, soil layers and erosion horizons also indicate a dry, cool, frosty climate.

Pollen records from the eastern South Island suggest an open grass- and herb-dominated landscape with some scattered patches of low-growing shrubs, perhaps similar to a dry, cold tundra. In response to lower summer temperatures, vegetation zones may have been around 1000 m lower. At present, silver beech forms treelines as high as 1100 m in the South Island, and mountain beech treelines form up to 1500 m. Therefore, these hardy trees almost certainly survived throughout. Since beeches are not known to disperse seed over distances greater than 6 km, the modern beech forests must have spread from pockets that survived the glaciation. However, the lack of wood or charcoal dating to the Late Glacial Maximum suggests forest was rare, restricted by harsh, dry climates.

The distribution of plant species confined to the southern part of the South Island, the ‘regional endemics’, further helps to define the glacial climate. Since few, if any, of them could have evolved in the short (geologically speaking) span of time since the glaciers receded, they must have persisted through the period of maximum climatic rigour. Most of them are high-mountain plants, and include some gems of the regional flora: species of *Celmisia, Ranunculus, Cheesemania, Aciphylla*, among others. Those now confined to the high plateaus of Central Otago and inland Southland were doubtlessly at home in cold, dry, windswept glacial tundras.

The glaciers began a rapid retreat about 19 000 years ago as a result of rapid global warming. However, the climate remained cool, windy and dry, probably averaging 2–3 ^{o}C colder than present for the next 7000 years. East of the Southern Alps, the low grassland and herbfield vegetation that dominated at the end of the glaciation was steadily replaced by shrubs and tall tussock grassland.

A rapid warming between 12 000 and 10 500 years ago began our current interglacial, the Holocene. Annual average temperatures became as warm as, or even somewhat warmer than, those of the present. Mountain glaciers retreated far up their valleys, and there were no major readvances for many thousands of years. Mataī, miro, tōtara and kahikatea increased massively over several hundred years to form the first continuous tall forests in the south and east of the South Island. Forests dominated by mataī, tōtara and kahikatea covered the lowland plains and extended up fertile valley bottoms into the montane regions from Southland to Marlborough. At the same time that lowland podocarps spread, mountain cedar, mountain tōtara, celery pine and bog pine began to occupy the upper forest zone in a vast swath that ran the length of the axial ranges. Celery pine and mountain tōtara dominated this zone, partitioning out the landscape, with celery pine occupying the most for nutrient limited sites. Only in Marlborough did mountain beech form a substantial part of the developing forest cover. In the very driest areas of the central south-eastern South Island, small-leaved shrubs and grassland continued dominant until 8000 years ago. After that time, tall podocarps, and mataī in particular, spread into all but the very driest regions.

The vegetation pattern of the southern South Island during the early Holocene suggests a lower but well-distributed rainfall and equable temperatures, with mild winters. Some trees and shrubs (for example mataī, miro, kahikatea and horopito) extended their range beyond current limits into the frosty upland basins of inland Canterbury.

From about 7000 years ago, the climate regime began to slowly alter from its previous mild state. Cool episodes began, marked by advances and retreats of existing glaciers. The first advances occurred about 6000 years ago, and built moraines that in some instances lie a kilometre or more down valley from the terminal moraines of recent centuries. In response to this cooling, silver beech began to increase throughout the southern South Island, both in coastal districts and in the interior, and mountain and red beech underwent a spectacular increase in north-eastern districts. On the mountain ranges of eastern Otago, Central Otago and Fiordland, silver beech began to move into celery pine and bog pine scrub, forming a forest-scrub mosaic in the moist and cool subalpine zone. The forest on the drier middle to lower slopes remained in tōtara and celery pine, grading down to the small-leaved shrubland-grassland of the driest valley floors. The final stage in the Holocene spread of beech forest was the explosive eruption of mountain and red beech forest in the south-western South Island beginning about 1500 years ago. Rimu in eastern districts began to spread from about 6000 years ago, at about the same time as silver beech, replacing mataī, miro and kahikatea on coastal plains and hills. Falling temperatures and increased south-westerly airflow seem to have been the major stimulus for these forest changes, bringing wetter, cooler winters, especially along the coast and the uplands of the interior. Soil deterioration must have also played a part as the fresh, rejuvenated soils of the late-glacial aged. Glaciers began advancing again between AD1600 and 1800 at a time of cooler temperatures, which has become known as the ‘Little Ice Age’.

3.2 Vegetation at the time of Māori settlement

Māori first settled New Zealand in the 13th century. The earliest sites in the eastern South Island consist of temporary villages along the coast and ephemeral moa hunting sites inland. These South Island sites are as old as those in the northern North Island, and it appears that Māori rapidly explored and exploited the whole country immediately upon arrival.

The coastal lowlands, plains, loess-covered downs and broad river valleys were densely covered with tall, podocarp forests. Only the broad river estuaries and lagoons were free of forest, and even here swamp forest of kahikatea and tall scrub of mānuka and saltmarsh ribbonwood provided a dense fringe to the reeds and saltmarsh. In the drier lowland sites with stony soils, such as the interfluves of the Canterbury Plains, stunted tōtara and tall kānuka forest formed the cover. However, on deeper or siltier soils mataī and kahikatea were as abundant. A number of drought-tolerant, broadleaved canopy trees and scrub were present, including ribbonwood, narrow-leaved lacebark, red matipo, kōwhai and coprosmas.

With increasing rainfall to the south and at higher altitudes, other tall podocarps, in particular miro and rimu, became more common and tree ferns and broadleaved understorey and canopy trees more prominent. In the eastern high country, there is gap of about 125 km between the Rakaia River and Lake Pukaki where beech forest is confined to scattered patches. Here, the lowland and coastal tall podocarp forest gave way with increasing altitude to mountain tōtara, mountain cedar, celery pine, bog pine, and, above 800 m, to diverse subalpine low forest scrub of broadleaved trees, dracophyllum, broadleaf, and a host of other scrub species. Outside of this central Southern Alps zone, beech forest of some description tended to dominate the montane-subalpine regions. In the north-east this was largely mountain beech with some red beech at lower altitudes, but with a strong representation of silver beech in the higher rainfall regions close to the Main Divide. In the south-east, silver beech and mountain beech shared dominance in the wetter western regions, along with red beech on warmer, more fertile sites. However, mountain beech was largely excluded from eastern districts where silver beech is the main upland beech.

The dry, central south-eastern districts of the McKenzie Basin and Central Otago are the more difficult to reconstruct in terms of pre-Māori vegetation cover, as they have been more thoroughly transformed by subsequent events. The dry inland valleys between the block mountains of Central Otago are at the climatic limit for continuous forest because of low rainfall and drought. Scanty fossil evidence from the valleys suggests that small-leaved shrubland of muehlenbeckia, matagouri, coprosmas and olearias was the main cover, with kōwhai and kānuka along river courses and on deeper soils, and thin grassland or mat herbs and shrubs on the droughtiest soils. It is debated to what extent mataī, miro and rimu penetrated the dry interior. There are pockets of soils and microclimates that could have sustained groves of these trees, but definitive evidence for them having been present is lacking. Rainfall rises rapidly with altitude, and celery pine, bog pine and mountain tōtara interfingered with the valley-bottom scrub on the mountain flanks. Fire from time to time would sweep through this highly inflammable vegetation. Charcoal of kānuka and mānuka accompanies that of celery pine at many locations, suggesting that they played a role in the succession of vegetation after fire. At treeline, a subalpine low forest of silver beech and celery pine grew in most areas, giving way upslope to a narrow band of shrubland, tussock and then herbfield.

In the areas marginal to these dry central districts, a complex mosaic of vegetation types was determined by soil patterns and prevailing climate. Mataī and tōtara forest appears to have predominated on better soils while celery pine and bog pine formed extensive stands in less favoured areas such as the droughty soils in the glacial outwash surfaces of the MacKenzie Basin. Where there had been disturbance by flood, fire or wind, a number of drought-tolerant broadleaves such as kōwhai, ribbonwood, broadleaf and kānuka would have been common. Grassland formed part of these lowland communities, but was never extensive, probably being confined to the lightest soils and bogs.

A tree or shrub cover was common on most wetland types, aside from those with permanent water at the surface or high salt concentrations. Kahikatea formed dense stands on regularly flooded swamp sites, and bog pine, mānuka and other shrubs tolerant of a high water table grew over all but the wettest portions of raised or valley-head bogs.

Fire occurred throughout the eastern South Island, but at a much lower frequency than at present or in areas of similar low rainfall elsewhere. Sparse evidence from soil charcoal suggests that fire return times could be measured in hundreds to thousands of years. However, in the dry southeast, a single fire could permanently change the character of the vegetation from forest to scrub grassland.

A large number of browsing birds existed in New Zealand before human settlement, and they were especially abundant in the drier eastern South Island. A range of moa fed on shrubs, tree juveniles, grasses and herbs. Flightless ducks and geese ranged through even the dry scrubland, grazing understorey herbs and tarn edges. It is not exactly clear how much impact they had collectively on plant communities, but the fact that many New Zealand plants are tough stemmed and resistant to browsing suggests that it was substantial. However, the impact of mammalian browsers – either because of their very different browsing techniques or because of their unprecedented concentrations under farming and pest outbreak conditions – seems to have been much greater. The near elimination of some plants under mammalian browsing and grazing regimes would argue for at least part of the flora to have been uniquely vulnerable to this new pressure.

3.3 Impact of Māori settlement

Soil and peat profiles from throughout the eastern South Island show ample evidence of devastating fire starting about 800 years ago. Charred tōtara logs are found from Marlborough to Southland; charcoal is preserved in soil profiles where there was soil instability following fire; and microscopic charcoal fragments become abundant in peats.

It is not possible to follow in any detail the course of these fires. However, it seems clear that it was repeated and probably deliberate fire that cleared most of the forested areas, not accidental conflagrations. The earliest dates for fire are in the lowlands, and there is some suggestion that firing of some inland valleys might have occurred up to 200 years later. By the time the initial firing was over, something approaching 75% of the forest and tall scrub cover of the eastern South Island had been destroyed.

The forest trees and shrubs of New Zealand are, almost without exception, vulnerable to fire and do not successfully resprout if charred. They have few adaptations to recolonisation after fire, lacking resistant underground rootstocks or heat- or smoke-triggered seed germination. A small group of non-forest, fire-tolerant or fire-favoured species therefore spread to an enormous extent once frequent fire entered the landscape. Thus a grassland, possibly at first dominated by smaller-statured short tussocks, blue grass and oat grass, but later tall (snow) tussocks, spread from the alpine zone and from pre-existing patches in the montane and lowland zone such as around rocky outcrops, dry ridges, along rivers, and on droughty soils in the major river valleys. While New Zealand grasses have probably not evolved with fire pressure, their morphology confers a certain amount of resistance to fire. Certain herbs, such as the Spaniards and some mountain daisies, share a similar morphology and also thrived. Bracken was the major beneficiary of fire wherever rainfall was moderate to high, and winter temperatures moderate. It thus became abundant in wetter, western districts, on the upper flanks of the inland ranges and along the coastal fringe. It was far less prominent in the driest regions. Repeated fire during the Māori era tended to reduce its dominance in all but the wettest areas, probably through consuming the organic-rich loamy upper layers of the soils and reducing soil fertility. In hilly, broken landscapes with numerous natural firebreaks, forest and scrub survived as patches even after intensive fire. Certain scrub and small tree species such as matagouri, kānuka, mānuka, and kōwhai had combinations of characters such as well dispersed seeds, ability to form seed banks, a preference for recently disturbed soil, or rapid growth that enabled them to increase their abundance and range as a result of increased fire.

By 200 years after Māori settlement, the pattern of the vegetation cover had become well established (Fig. 1). Rainfall and topography dictated the amount of woody versus fern or grassland cover. The wetter western districts close to the Main Divide retained most of their subalpine, and large amounts of montane, forest cover, although it is noticeable that the cleanout of previous forest was more complete within the central beech gap and in the central south-eastern districts. Here, tussock grassland and scrub now ran in a continuous sweep from valley floor to alpine herbfields. Below 600 m, destruction of tall forest was also near complete. In its place grew short tussock grasslands, scrub and fern and patches of regenerating low forest.

After the large burn-offs that set the pattern for the next 500 years, small-scale burning continued. While the reasons for this continued burning are speculative, they are most likely to be connected with the large-scale seasonal movements by Māori throughout the high country during summer. While Māori settled only along the coast in the South Island, the inland resources being insufficient year round and the climate too hostile for permanent settlement, in summer mobile groups exploited the food and other resources of the interior. Fish, eels, koura, birds, bracken root, and tī were found there, and the greenstone of the West Coast could only be obtained by travel over the alpine passes. Regular firing kept the valley and mountain pass routes open, and improved visibility. An additional benefit of fire was the way it encouraged establishment and growth of starch-rich bracken and tī.

Frequent burning had a dramatic effect on wetlands. Swamp forests and scrub cover of bogs vanished. Greater runoff followed the destruction of the forest, and lagoons and swamps with raupō and reed vegetation proliferated. In the uplands, removal of forest increased the wetness of the soils, and wet, herbaceous valley-head and spring bogs replaced the previous drier, scrubby bogs.

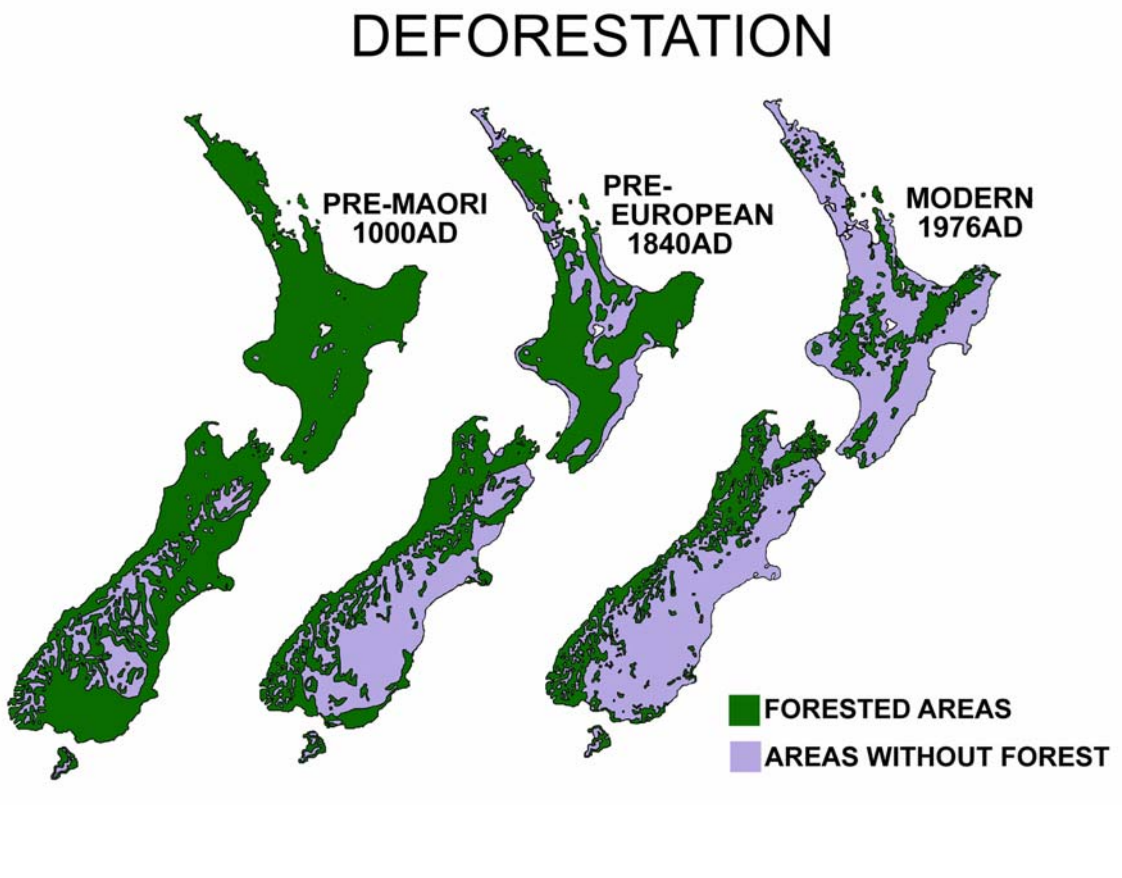

Fig. 1 Changing extent of forest during human settlement.

3.4 Impact of European settlement

Initial settlement

With the appearance of whalers, sealers and the occasional trader off the southern coasts of New Zealand in the late 18th century, the pattern of Māori settlement changed permanently. First, the Europeans acted as a magnet for Māori as they became an increasingly important source of trade, and settlement consolidated at ports suitable for shipping. Second, the introduction of European crops – first potatoes and other root crops, and then wheat and other grain crops – and domestic animals, transformed the Māori economy. The vast seasonal cycles of hunting and gathering in the interior country halted.

There was an immediate response to the cessation of fire over the 50 years between contact and European settlement. Dense scrub and Spaniard thickets spread along the previously burnt routes of the main valleys and subalpine and montane scrub in the ranges. However, 600 years of burning had reduced the amount of scrub and forest in some tracts of grassland to vestigial remnants. In the drier regions, the once ubiquitous celery pine had been virtually eliminated and tōtara confined to natural firebreaks on cliff and scree edges and rocky outcrops. The response of the tussock grasslands to this 50-year pause in fire was therefore muted, as there was often little scrub or forest species capable of responding. However, over very wide areas that are now in near pure grassland, a much larger scrubby element persisted into early European times.

Beginning in the early 1840s, nearly all of the lowland plains and downlands of the South Island were pastorally occupied by the early 1850s, and the inland high country occupied by the late 1850s and 1860s. Sheep numbers rose rapidly through the 1860s, and peaked at over 11 million stock units in the late 1870s. The advent of what Kevin O'Connor has termed 'exploitative pastoralism', that is pastoralism that lives off the biotic and physical capital of natural vegetation and soils through grazing on unimproved grassland, did not change to any great degree the broad pattern of forest and grassland established some 500 years previously by the Māori.

However, collectively, the impact of grazing, burning, weeds and pests transformed the nature of the high country grasslands. The first effect was the rapid decline of palatable shrubs, native herbs and grasses such as carmichaelias, anise and *Elymus* under the browsing impact of millions of sheep and rabbits, augmented by goats, hares and pigs. The second was the impact of regular grass fire cycles used to stimulate fresh foliage from tussock grasses that provided poor forage otherwise. The result was a gradual decline in the stature, vigour and cover of the main tussock species. And finally, the pasture grasses and forbs, and the inevitable accidental release of dozens of aggressive weeds, began to dramatically alter the functioning of native communities. Gorse, broom, briar, willows and pines among others formed new scrub and forest communities; introduced forbs and mat-forming plants such as sorrel and hawkweeds began to eliminate competing native inter-tussock species. Dense sward-forming introduced grasses in places totally suppressed native species dependent on open vegetation in which to regenerate.

The post-1950s

By the 1950s the consequences of 100 years of exploitative pastoralism were apparent in much lower stock numbers and effective exhaustion of soil fertility over much of the unimproved ranges. Native vegetation was also at a low ebb, palatable species having been nearly eliminated as dominants, tussock vigour reduced, and many scrub species reduced to non-regenerating remnants through browsing and suppression of regeneration by fire and exotic grasses. However, the post-1950s solutions of oversowing, fertiliser application, fencing, improved cultivar selection and stock management, while demonstrably beneficial to ground cover and production, were arguably as damaging to native vegetation as what had gone before. Debates broke out among conservationists and landholders about the best way to protect the tussock grasslands, and whether a continuing fire and grazing regime over unimproved uplands was sustainable. It was also unclear at that time to what extent invasion by exotic weeds, such as hawkweeds, was a consequence of pastoral practices.

Pressure grew towards the end of the 20th century for conservation of non-forest lands in largely indigenous cover. It was confidently expected by many that cessation of fire and grazing regimes would lead to re-establishment of structure and function of native ecosystems and slow down or reverse invasion by exotics. However, these conservation suggestions for improving the situation for native vegetation have proved to be problematical as well. There is now a great deal of evidence that native species richness is declining across non-forest country and that exotic weeds continue to increase even in forested ecosystems independent of land management practices. Cessation of grazing and fire regimes has variable consequences for the indigenous elements because of the interaction of exotic weeds and fertility levels. It is now apparent that simply stopping what are seen to be damaging pastoral practices will not be sufficient. If self-sustaining, native-dominant, mostly weed- and pest-free conservation areas are wanted – whether ultimately in tussock-grassland, scrub or forest – they may need to be actively managed for those ends.

4. Conclusions

4.1 Maintaining and enhancing biodiversity in the South Island high country

A detailed examination of the relationships between management practices, such as fire, stocking rates, fertiliser inputs, pasture development and weed and pest control on one hand, and ecological and biodiversity values, which should underpin future decision-making for land management, lie outside the scope of this article. However, some broad points can be made.

As far as vegetation is concerned, the key conservation question in the high country is what sort of vegetation cover will preserve the greatest range of indigenous biotic diversity in the face of human-induced pressures. From a vegetation point of view, the tussock grasslands and their associated patches of wetland, shrub, scrub and forest maintain most of the original plant biodiversity, albeit much of it enormously reduced in abundance. However, from an animal point of view, the lack of extensive tracts of woody vegetation and the huge reduction of certain elements severely restricts their biodiversity. Birds in particular are limited by lack of woody vegetation. Many insects too are dependent on twiggy foliage and bark, or endemic to certain trees and shrubs. And some soil invertebrates and fungi specialise on forest soils and litter. Trees and shrubs tend to be deeper rooting than grasses, and intercept and evaporate more rainfall, therefore markedly altering the hydrology and fertility of the soils. The shallow, sour, waterlogged soils of many upland areas are at least in part a consequence of 700 years or more of deforestation. It is therefore increasingly realised that woody biomes not only were the original landscape cover before humans, but that they offer marked benefits in terms of biotic diversity, pest and weed supression, and soil structure and fertility.

The nature of the original vegetation cover that existed before the advent of deliberately lit fire and browsing mammals is a starting point for thinking about what might constitute a stable and biodiverse landscape cover. However, so much has changed in the environment that it can be only a guide not a blueprint. Current scrub and forest patches within the induced grasslands largely consist of species that were subordinate or niche elements in the original vegetation. The dominants of the original woody cover are, without exception, hypervulnerable to fire. However, they are in many areas also the biome that is least fit for the current fire-prone and exotic-dominated landscape. Native scrub and forest recovers poorly after fire, is often outcompeted by fire-favoured exotics, suppressed by exotic grasses and herbs, and in many places invades slowly into grassland.

These factors make it unlikely that simply eliminating fire and grazing will result in a suitable biodiversity outcome in all places. In some areas, indigenous grassland or low shrubland has been for so long the sole cover that it does not have within it the resources to progress towards a more original state. However, it remains vulnerable to invasion by exotics. In others, especially the higher rainfall areas, substantial sources of forest and tall scrub seeds remain, and change could be rapid. It is clear that progress towards establishing native woody biomes – if this is the desired outcome – will be slow and will need innovative management and careful integration with the wider productive landscape.

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