REVIEW OF SOUTH ISLAND HIGH COUNTRY LAND MANAGEMENT ISSUES

Joint submission to the Ministerial High Country Review Committee from the New Zealand Ecological Society and the New Zealand Society of Soil Science

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The version published here has been edited to remove minor errors and to ensure stylistic consistency, but is otherwise that submitted to the review working party.

These two scientific Societies appreciate the opportunity to comment on the important question of sustainable land management for the South Island high country. We recognise that considerable thought has been put into the questions we have been posed. We also recognise that some questions pre-suppose a particular viewpoint with which the scientific community may not agree. For this reason, we wish at the outset to make our position clear.

We present this position statement before attempting to answer the questions you have posed to us. Please read this first for two reasons: (a) it provides background which we do not intend to repeat in relation to each question; and (b) we take the questions, or groups of questions, as issues about which we present scientific commentary, but do not repeat the background each time.

Background Information

Historical

There may be some parallels with the history of land problems and solutions in the North Island in the early part of the century. Problems (e.g., land degradation) developed within about 50 years of forest clearance in the North Island, but the process has been slower (up to 150 years) in the South Island high country. The solution in both cases may be to ensure nutrient balance between removals and replacements in managed, productive ecosystems.

There is now a need not only to learn from the past, but also to look positively to the future and to seek a wide range of solutions which are not exclusively concerned with production (conventional pastoral and forestry), but which will include shrub-based systems and other kinds of enterprises (e.g., tourism). Such diversity of enterprises may assist short-term economic sustainability (see Sustainability below) and help to safeguard New Zealand's natural heritage, functioning ecosystems and indigenous biota.

Sustainability

We are aware of the definition of "sustainable management" used in the Resource Management Act, which is being widely used today. This definition is not entirely appropriate in an ecological sense for the following reason. For an ecosystem and its management to be sustainable in an ecological sense, there cannot be an excess of removals (nutrients, energy, or water) over inputs. In the longer-term we would argue that to be economically sustainable any system must also be ecologically sustainable. Whilst short-term solutions to high country problems (such as rabbits and *Hieracium*) must be affordable to land occupiers, the longer-term maintenance of the nation's productive potential will depend on achievement of ecological sustainability as well (NZ Ecological Society Statement on Sustainability, 1992).

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Value judgements

Many questions contain words which imply value judgements (such as "degradation", "rehabilitation" and "fragile systems"). We try to avoid such value judgements, although science in itself has its own value judgements. We attempt to present a scientific viewpoint without pre-judging economic and social questions which are outside our field of expertise.

High country environment

It is not possible in a few words to summarise the characteristics of the high country environment, but certain key points need to be understood in relation to soils and vegetation.

GEOLOGY is remarkably uniform, consisting of two main rock types (greywacke and schist). These are similar in mineral composition, but different in physical form, which explains the much greater tendency for erosion and scree formation on the greywacke. Land uplift is recent in geologic time, and present day geological erosion may be rapid near the main divide. The high country landscape has been largely influenced by glacial processes of erosion and deposition.

SOIL FORMATION depends heavily upon underlying rock, associated loess and climate, modified by the influences of topography, vegetation and humans. The extreme range in soils, from semi-desert to alpine, is related to the extreme range in rainfall, temperature and continentality from east to west, and also to altitude from *c*. 200m to >2000m.

EROSION and subsequent revegetation are now known to occur more rapidly under wetter conditions in the west, than under drier conditions east of the main divide, where erosion effects may appear to be more severe, but where, in reality, erosion rates are relatively slow (Basher and Tonkin, 1985). Although variable, rainfall in drier areas is not of high intensity by world standards. Soil erosion by water is therefore not usually serious, especially where there is complete vegetative cover, but occasional, localised, severe catastrophic gullying does occur (Pierson, 1980, 1981). Wind erosion is probably the most important process causing soil loss in the high country, and is greatest where bare ground is most extensive.

NATURAL VEGETATION patterns are strongly influenced by soil distribution, and by climate (including altitude/aspect) but these have been much modified during the last 1000 years by humans through burning, grazing and agricultural development (Wardle, 1991). There are some contrasts between Otago and Canterbury. For example, much of the variation in vegetation in Otago is related to altitudinal lapse rates of climatic parameters, whereas in Canterbury there is a greater dependence on soil fertility and textural variation. Some of the characteristics of the native vegetation include: long-lived, slow growing perennials (adapted to poor, leached soils in the absence of mammal grazing); periodic seeding; few deciduous species; few annuals (except in semi-arid areas); few herbaceous legumes; tussock growth habit changing to cushion form under grazing pressure; tussocks accumulating high above-ground biomass.

Some ecosystem concepts

It is not possible to change one ecological factor without having effects on other characteristics of the ecosystem.

Tussock grasslands are grasslands because of a combination of natural and human-influenced factors. These include a long history of occasional fires since Polynesian occupation. The continental notion of fire being a dominant influence in the maintenance of grasslands may not be so applicable in New Zealand where, although natural fires still occur, other factors are also important. Large areas (prior to Polynesian times) were covered in beech or totara forests, and were not grazed by mammals. Much of this was destroyed around 700 BP (before present). The factors which now maintain the tussock grasslands under a grassland vegetation include grazing (total herbivory, see below), without which a return to forested/woody species conditions would be likely, except in the driest areas. In reality, parts of the high country may have passed an "ecological threshold" and be evolving towards new and different systems. The relatively recent and rapid spread of *Hieracium* species could be an “indication” of this shift from one state to another. Such shifts may be triggered by relatively minor perturbations.

Total herbivory in the high country includes defoliation by insects, rabbits, hares, etc., as well as by domesticated livestock. Total herbage biomass can be estimated, but annual productivity is a small proportion of biomass, and this determines the total “carrying capacity”. Management decisions, stock control and type of vegetation determine how much of the available herbage mass is consumed, how it is shared between the "consumers", and therefore what is available for domesticated livestock.

The potential biomass production of a site is determined by the environmental conditions at the site (temperature, moisture, soil) and there will be competition among the available species to achieve that level. The main features of variation in potential productivity and suitability of species between sites is interpretable in terms of four factors: temperature, moisture, soil fertility, and grazing (Scott *et al*., 1985).

The high country can be regarded as a mosaic of land units, each with its suite of soil and environmental factors, biota and production characteristics, relatively uniform within, but contrasting between, units.

The output response characteristics of each land unit to different inputs (e.g., fertiliser) and management (e.g., grazing control, burning) are variable and determine the economic viability of different production options. For example, high fertiliser requirements of some infertile, high altitude soils cannot be justified by low pastoral outputs.

Land units need to be managed according to their individual characteristics. Land units with high potential production and favourable environmental conditions have wide tolerance to management, whereas land units with low potential production under more adverse environmental conditions show less resilience to mismanagement. A consequence of this is that the need for subdivision to control grazing is high in the high country, where selective pressure on preferred vegetation (and burning) could have serious consequences.

The intentional or unintentional introduction of new species will alter the ecological options (and outcomes) within an area. Examples include the introduction of:

(a) legumes and grasses for pasture improvement;
(b) domesticated and feral grazing and browsing animals for production and/or hunting;
(c) trees for forestry (note the potential for wilding spread);
(d) weeds including *Hieracium*, briar, gorse etc;
(e) reintroduction of indigenous trees, shrubs and tussocks.

Note that some of these introductions may be irreversible.

Primary production in more extreme environments tends to be dominated by cellulose production (compared with a wider range of products in more favourable environments). There is, therefore, a limited range of managed production options for the high country. In the past this was dominated by pastoral production, and there is increasing interest in forest production. There is also increasing interest in alternative land uses, such as recreation, eco- and adventure-tourism, and nature conservation.

Nutrient balance is a prerequisite for ecological sustainability. The input of essential plant nutrients (especially S and P in the high country) through weathering and fertilisers, must equal or exceed the output of the same nutrients in harvested products, leaching losses or other removals, such as erosion and burning losses and nutrient transfers.

Note that grazing systems and N-fixation by legumes tend to unbalance the proportions of cations and anions in the soil and lead to increasing soil acidity, which for long-term sustainability must also be corrected by liming (McIntosh, Allen and Patterson, *in press*).

Techniques are available for assessing the status of ecosystems and their component parts. It is important to assess not only current status, but also direction and rate of change. In the past Catchment Boards carried out "Condition and Trend Analysis" which was valuable in this regard, although it is unfortunate that soil properties were seldom recorded.

Soil parameters are good indicators of the combined effects of ecological factors and management conditions over the medium to long-term, because they are relatively slow to respond compared to vegetation parameters, which better reflect short-term change. Soil parameters include depth, amount of litter, organic matter content and quality, nutrient availability, moisture capacity, compaction and pH.

Vegetation parameters include indicator plants, biomass, community structure and composition, diversity and ground cover. A wide range of parameters can be and has been measured, but records are not always easily accessible or readily interpreted. There is a need for more work on interpretation of monitoring data. Some long-term vegetation recording sites are available (Meurk and Buxton, 1991) as well as the Landcare Research database of permanent plots in forest and grassland, Espie and Meurk's grazing trials in the Mackenzie, and some Lincoln plots on Mt John (see Questions 15, 16). Interpretation of data from these, and guaranteeing their maintenance and security, is the highest priority. There is also an urgent need for the establishment of protected natural areas to provide base-line information, and new permanent monitoring sites to assess both temporal and spatial changes.

Natural systems tend to evolve to become more conservative of nutrients and energy, whereas systems modified for higher pastoral production will have higher biomass production but higher inputs, and may be more liable to nutrient losses. Some plant species are clearly advantaged by grazing - see Lord (1990).

Biodiversity

There are two aspects of diversity which are important in the high country context: number of species, and distribution of biomass between species.

Flora

Overall the number of species present in New Zealand has been nearly doubled by introduced species: this is less so in the high country than in most other areas, but it is estimated there has been an increase of some 30% in grasses, herbs and annuals. In this sense, "biodiversity" may appear to have increased. In reality the native species have been displaced by exotic introductions and a significant proportion of their geographic range and genetic diversity has been reduced. Biodiversity of native species has been reduced.

There are no known extinctions of native plant species, but several species are on the brink of extinction (e.g., *Carmichaelia prona)* and the populations of others (*Carmichaelia kirkii, Swainsona novae-zelandiae* and *Helichrysum dimorphum*) are very restricted. Intensified agriculture or forestry developments could threaten other native species which have no high altitude refuges.

There are indications that the distribution of biomass between species has been reduced in recent times (i.e., the dominance of a few species has increased). It has been suggested that maximum diversity occurs at intermediate ecological successional stages (Grime, Hodgson and Hunt, 1988). Grazing of dense tussock vegetation with a localised narrow range of species is likely to increase the number of species in that local area by reducing the stature of the dominant tussocks. On a regional scale, however, species intolerant of grazing are likely to be eliminated from accessible sites and, in this sense, biodiversity is reduced (Dickinson, Mark and Lee, 1992; Hunter and Scott, 1993).

Fauna

Numbers of native species are known to have decreased (e.g., moas, wekas, as well as invertebrates, reptile fauna and soil micro fauna; Bell, 1986), while introduced species (sheep, cattle, deer, pigs, goats, chamois and thar) have increased. It is of note that the moth fauna has been dramatically reduced by the introduction of exotic grasses and has not been replaced by an exotic moth fauna (White, 1991). Other introduced animals include mustelids, rodents, rabbits, and possums, so an increase in the number of species *per se*, should not be regarded as an unqualified “good thing”.

Hydrology

Maximum water yield may be obtained from landscapes largely devoid of vegetation (sometimes called denuded landscapes). However, this is not always the case in New Zealand high country (Mark, Rowley and Holdsworth, 1980). Denuded landscapes are also accompanied by greater frequency of floods because hydrological response time to rainfall events is very rapid, and erosion risk is also higher than on well-vegetated lands. Many international concepts of the hydrological cycle were developed in USA and need to be modified before they are applicable to New Zealand conditions (Hayward, 1980). Examples include:

(a) new Zealand rainfall and humidity is high by world standards;
(b) rainfall intensity is generally low in New Zealand;
(c) in New Zealand catastrophic rainfall events are rare, or very localised in their effects;
(d) lowland floods do not usually come from denuded high country areas;
(e) riparian zone is more critical for lowland flooding ..... this is important as it was related to the policy to replace cattle grazing by sheep when the significance of the damage to riparian zones by cattle was appreciated. Retention of vegetation on riparian margins is essential to minimise adverse effects.

There are differences of opinion and evidence regarding the significance of fog and cloud droplet interception by tussock vegetation. It may be very important in augmenting water yield (Mark *et al*, 1980); on the other hand the value of moisture captured by this process may be largely confined to plant survival. However, there are differences of ecological opinion on the relative effects of bare ground and different vegetation types on transpiration rate and water yield.

Responses to Questions

Pastoralism

Q.1 Under what conditions does pastoralism degrade the high country resource?

Q.2 Is there a place for pastoralism in tussock grasslands? If so, to what extent?

Before answering these questions, two terms require clarification: “Pastoralism” we take to mean the extensive grazing use of the land without application of fertiliser or other inputs (called “exploitative pastoralism” by O’Connor, 1982). This is a narrow definition of pastoralism and excludes what can be called “pastoral farming”, which does include fertiliser inputs. “High country resource" we assume means the biophysical resources of vegetation and soil.

In the long-term, pastoral use of the high country can only be sustainable if outputs (e.g., wool, surplus stock and meat, and leaching and burning losses) are balanced by inputs (e.g., weathering, rainfall, etc.). Under the traditional extensive grazing system, nutrient losses have been unnoticed for a long period, but have been substantial (O'Connor and Harris, 1991). Only recently has effect of the imbalance become obvious.

It follows from this that there is a danger of assuming sustainability if there is no indication of change (deterioration). This in turn means that sensitive indicators (early warning indicators) of change in the biophysical resources are needed.

The most important "degrading" factors are those that lead to nutrient, biomass and species losses from the system. (Note that the boundaries of the system need to be defined.) The factors include grazing, burning and the natural process of leaching. Where these removals and losses are balanced by gains from natural processes such as weathering and rainfall inputs, or artificially through fertilisers, sustainability is possible. Even if there is only a very small negative imbalance between inputs and outputs, long-term sustainability is not possible, and the consequences will become evident sooner or later. The danger is that very slow, incremental change will occur until some threshold is reached and then a catastrophic collapse of the system could follow with very little warning. Potential indicators of impending disaster are urgently needed.

Evidence that adverse changes are happening is provided by observations of reduced tall tussock cover, reduced faunal and floristic diversity, and lowered levels of soil nutrients and carbon (organic matter).

It is probable that there are only a few instances in the high country where natural release of nutrients (weathering, etc.) balances removals and losses. Only in these instances is the traditional pastoral system truly sustainable. More usually the drain of nutrients leads to undesirable consequences (O'Connor and Harris, 1991; Treskonova, 1991).

Indicators of change need to demonstrate direction and rate of change, in addition to present condition. Biophysical indicators include: (a) soil quality, (b) water quality, (c) soil erosion, and (d) weed population. "Degradation" or undesirable change in these indicators would be demonstrated by, for example: loss of nutrients (total pool and differential losses); increasing soil acidity; decreasing soil organic matter (humus); reduced biomass; reduced vegetation cover; increasing soil erosion and bare ground; increasing solute content in water; increased compaction; greater run-off; an increasing weed population; and, sometimes, decreasing biodiversity.

Such indicators are more useful in combination than in isolation. Much information is stored in old records (e.g., Ministry of Works, Catchment Boards) but is not easy to access. Furthermore, the data are only as useful as the interpretation which is possible from the data set. At the present state of knowledge, good interpretation to assess sustainability is not possible and it is not co-ordinated nationally. More work is needed in this area.

The practical reality at the present time is that the nutrient equation is not fully quantified. Until it is, we suggest a conservative management policy, with burning and associated grazing management in accordance with the guidelines produced by the New Zealand Mountain Lands Committee (Anon, 1992). Some ecologists would argue that burning of shrublands should be abandoned apart from exceptional circumstances: and even in the case for stock access, mechanical or chemical means should be preferred.

For nature conservation reasons, some ecologists take the extreme view that there is no place for pastoralism in the high country, because there are so few native species which are adapted to withstand the effects of grazing by domesticated animals. However, one of the dilemmas of conservation management is that some species may be disadvantaged without grazing. Indigenous species are likely to do better in "degraded" or leached land or after removal of topdressing, since the competition from exotic grasses, legumes, and weeds is reduced (Meurk, Norton and Lord, 1989).

Q.3 What additional research is required in tussock establishment?

Q.4 Should degraded land be rehabilitated? If so, for what reasons and in what circumstances?

We approach these questions together because they are both related to tussock replacement or restoration, if that is possible. We believe that at least three approaches are possible:

(a) "Improvement" of high country land for pastoral purposes by, for example, oversowing and topdressing. This may be acceptable under the appropriate conditions, which are broadly the mid-altitude lands with sufficient rainfall.

(b) Management to encourage the enhanced growth of tussock species.

(c) Development of new technology to allow mechanical planting of tussock seedlings reared under nursery conditions.

Pastoral "improvement" with oversowing and topdressing is usually assumed to be a sustainable option so long as the required maintenance fertilisers are applied. However, some recent research is showing that even this may be inadequate in some cases (Ogle, Patterson and Patterson, 1993; McIntosh *et al., in press*).

We do not consider that oversowing and establishment of tall tussock grassland from seed is realistically possible. However, there may be possibilities of establishing some other tussock species from seed. Several kinds of research are needed: that required to determine the most promising species, technology for seed collection from native plants, and the development of seed supplies for those wanting to try.

We also consider that Q.4 is too restrictive in that it assumes "rehabilitation" is the only option. We believe that there is an increasing range of new enterprise options (such as novel crops and viticulture, but not all involving biological production, and including tourism-related ventures) which it is appropriate to consider. However, such developments should only proceed in the context of safeguarding the full range of the remaining indigenous ecosystems in New Zealand.

However, there are situations where attempts to restore tussock grassland may be appropriate and justifiable. Such might include:

(a) for soil and water conservation;
(b) to preserve habitat for a representative range of indigenous biota, including rare plants and animals (including invertebrates);
(c) to restore landscape quality in highly visible places (e.g., Tekapo/Mackenzie); and
(d) to retain functional indigenous ecosystems.

For soil conservation reasons it is highly desirable to attempt to at least retain, and preferably increase, vegetative cover. However, it should be realised that not all vegetative cover (e.g., weeds) is always desirable. “Degraded” land should be rehabilitated to retain effective plant cover and achieve adequate soil conservation. Research is needed to achieve this on a management scale in many areas.

Where it is intended to attempt to restore tussock grassland, two approaches may be possible. Introduction of seedlings raised under nursery conditions, by mechanical means (analogy with cabbage planting machines), may become possible on gentle terrain in the future. This will require research effort and time to develop the technology (and the will and funding to achieve this), and is likely to be expensive and therefore only justifiable under special circumstances. It is likely, however, that where existing tussock cover is negligible, or weed invasion is severe, this may be the only method which has any likelihood of success. Some research has recently started but it is estimated that the technology is some 10 years distant.

The second approach involves management change to favour the growth and spread of the desired species. In this case, research is needed to confirm the management changes which will be required, and to obtain more information on the competition factors which are operating between the desired and the less desired plants. We believe that the prospects for this are good in that, if the research is successful, the methodology will be less prohibitively expensive than mechanical transplanting.

An alternative approach, advocated by some ecologists, involves the re-establishment or encouragement of shrub growth, and particularly matagouri, which could be later thinned to a manageable grazing woodland system. There are a number of desirable features of such systems (C. Meurk, *pers. comm.*) and research into the management of such systems is needed.

One of the competitive factors limiting tussock recruitment is grazing pressure. It has been shown that tall tussock regenerates when grazing pressure is less than 0.2 SU (stock units) per hectare (Lee, Fenner and Duncan, 1993). Even this has been questioned and, under some circumstances, the critical stocking rate could be less than 0.1 SU per hectare (K. O’Connor, *pers. comm.*). It is important to take account of total herbivory, not simply grazing by domesticated stock.

A further question related to competition is that of why some introduced species (e.g., *Hieracium*) are better competitors than native or other exotic species. Further research is needed to resolve this important question, not only to work towards tussock recovery, but also to plan for the control of undesirable exotics.

Forestry

Q.6 What are the arguments for and against the natural revegetation of degraded lands by wilding trees?

Q.7 What is the role of forestry in providing sustainable land use?

We will argue later that there are both beneficial and undesirable aspects of forestry in the high country. The main arguments against forestry, aside from whether the trees are desirable or not, concern the threat of wilding spread, and the visual impact on landscape. If forestry is to be acceptable in the high country there are two features of tree introduction which must be under control. The first of these is the selection of suitable sites (which should be both ecologically and visually acceptable), and suitable species for those sites, and the second is that any threat of spread beyond that site must be containable and contained.

Research has shown that trees can have beneficial effects on mobilisation of organic matter calcium in the upper soils, and perhaps obtaining nutrients from greater depths than grassland plants (Davis and Lang, 1991). This may result in an increase in the number of grass species following tree-felling, which may be related to a release of nitrogen from surface soil organic matter due to aeration and soil disturbance (Vitousek, 1981). It has also been suggested that trees may be able to utilise sources of nutrients unavailable to other plants (K. O'Connor, *pers. comm.*). Some trees may thus provide a means of relatively economic site improvement.

However, most of these beneficial effects are related to observations on short-term crops of trees out of former pastoral land. It may be, for example, that the beneficial effects derive from a system which simply mines nutrients from greater depths than grassland. Under permanent, natural coniferous forests other effects are known to be less than beneficial to soils: these include the prevention of germination of other species, deleterious effects on water catchments and water yield, acidification and the podzolisation process, and enhanced leaching associated with litterfall from conifers. Acidification of waterways may also be associated with such forests, but this is not easy to separate from acid rain effects in the northern hemisphere. Long-term (several rotations of trees, or up to perhaps 200 years) studies and observations may be needed to sort out the balance of these beneficial and other effects under New Zealand conditions.

Forest production rotations are of course much longer than farm crop rotations. This has the benefit that there is a longer period in which to learn from mistakes, but on the other hand it is more difficult to revert to other forms of land use.

It has been shown that growth rates of trees in the high country compare favourably with those elsewhere, at least in the more moist areas where water is not a serious limitation (Ledgard and Belton, 1985). All the economic indicators suggest that there is a bright future for forestry.

Some ecologists and soil scientists believe that for both soil conservation reasons and economic reasons there is a big future for forestry in the high country. This is not to say that ecologists or soil scientists necessarily favour such development, but rather that economic forces may render it inevitable. This implies that a comprehensive governmental land management plan is necessary to protect other valid forms of land use, including natural indigenous ecosystems.

Ecologists and soil scientists are aware that there are also negative aspects of forestry. These are concerned with the visual impact of tree plantations on the landscape, with the possible long-term acidification and soil leaching enhancement processes discussed above, with impacts on water yield (Fahey and Watson, 1991) and the effects on natural ecosystems and habitats.

There is also a fire risk associated with forestry which needs to be evaluated in relation to the fire risks and tolerance of tussock grassland. Fire risk is probably another factor, like the threat of wilding trees, which requires a planned pattern of forestry and intensive pastoral farming to be developed to minimise the risks.

It has been calculated that there are some 2 million hectares of high country land with forestry potential, but it is likely that in competition with demand from elsewhere that only some 200,000 ha are likely to be planted in the foreseeable future (A. Nordmeyer, *pers. comm.*).

We therefore believe that the ecological challenges are to ensure that the most suitable 200 000 ha are planted with the most suitable species, and that planting and spread is contained. If the growth of a forest industry is almost inevitable, then we need to look ahead and visualise the high country with 200 000 ha of trees, and to plan where those trees will have the most benefit and the least undesirable impacts. A national strategy is required, and perhaps the best way to ensure this would be through a National Policy Statement, under the Resource Management Act.

Some suggestions are that trees would be preferable in wetter than drier areas, and below an upper limit of *c.* 1000m. The upper limit would be related to potential growth rate and therefore also roughly follow, but be below, the natural tree line. This would ensure that exotic forest planting would have a buffer of native woody species above it. Ideally, some planting of native trees (mainly beech) should be considered around all exotic plantings, to both reduce spread and provide a visual barrier.

Because of the effects of logging and the erosion potential on steep slopes, gradients greater than 25 degrees should not be planted. It is also important to realise that, even if soils and climate are suitable, and growth rates are good, steep topography and difficult access may make forestry marginally economic. Successful trial plantings are all on fans, terraces and footslopes of hills. The potential of steep slopes remains largely uninvestigated.

One method of minimising the threat of wilding spread is to develop "safe" trees such as the sterile Leyland cypress and the presently experimental *Pinus attenuata x radiata* cross. Research in this area will, of necessity, be long-term, but should be encouraged, and the costs of the downstream externalities will be up front.

Prior to planting trees with any potential for wilding spread, plans to contain such spread would have to be in place. Localised intensive grazing pressure, with inputs of nutrients to allow the ecosystem to withstand this, may have a place in control strategies. Likewise, the juxtaposition of forestry blocks and intensive farming may have a place in minimising fire risks.

This would suggest that a total land use plan may be needed, and that conversely a *laissez faire*, or market-driven approach to land use would not contain the potential problems. The pros and cons of these approaches have been discussed recently (Wardle and Foran, *in press*). If a total land use plan was to be developed, it would need to be with community involvement and consent (scope for LUPIS perhaps?). The total plan would also have to make provision for all sorts of other demands such as landscape values, conservation areas, recreation and public access, and water supply, and have sufficient flexibility to allow for new future options.

Biodiversity

Q.8 What is the trend in losses of indigenous biodiversity? What are the effects of weeds and pests on biodiversity? What are the implications for future land use?

Q.9 Have the heritage values of biodiversity been adequately protected in the high country?

The twin features of species numbers and dominance have been discussed in the introduction to this submission, both with regard to plants and to animals.

There are no known extinctions of plants, but there are many examples of threatened plant loss and actual animal loss (including invertebrates) as these have been replaced by introduced grazing and browsing animals.

Under the influence of pastoral development there is a trend towards dominance by a small number of plant species (which may be native or introduced). On retirement from grazing, diversity has been shown to initially increase in most but not all cases. (See discussion on biodiversity in introduction.)

Biodiversity (i.e., indigenous biodiversity) decreases as a function of "degradation" on most areas of high country, and may decrease somewhat with restoration of a natural tussock cover (Dickinson *et al.*, 1992). Natural biodiversity appears to decline in relation to increasing numbers of weeds and pests.

Effects on invertebrate populations have been reported by Yeates (1974), who found that in Otago tussock grassland, the nematode fauna clearly indicated the effects of fire on species diversity for several years after a burn.

Total fauna biomass (including soil micro fauna) and invertebrate fauna biomass are not known so the effects of cultural systems on these parameters cannot be assessed. Because of the roles of these organisms in recycling processes, and the importance of recycling in the maintenance of sustainable systems, it is important that research be conducted on these biota.

Some ecologists deduce from the reported changes in biodiversity, and other biophysical observations, that physical limitations should be put on where farming should be permitted. One suggestion is that farming should be confined to those land units which respond to oversowing and topdressing.

There is no biophysical information to show that any ecosystem managed for production (farming, horticulture, or forestry) is sustainable. By contrast, there is increasing evidence (biodiversity, soil acidification, decrease in soil organic matter, etc.) to suggest that managed ecosystems in the high country are being exploited, leading to depletion of resources (Ogle *et al.*, *in press*; McIntosh *et al., in press*; Hewitt, *in press*). This, in turn, suggests a need to change our systems of land-use to systems which are both economically and ecologically sustainable.

We do not believe that the heritage (or scientific reference) values of representative high country communities have been adequately protected. There is a need to protect natural areas, reserves, and permanent monitoring sites from threats from grazing, fire, and wilding tree spread. Furthermore, the PNA programme is far from complete in the South Island high country, and without thorough survey, and the implementation of the programme, heritage values will not be adequately provided for.

Soils and Erosion

Q.10 What is the relative importance of mass movement of soil in pastoral farming and in the DOC estate?

Q.11 What is the extent and implications of soil surface erosion through wind and water?

Q.12 How have soil biota levels changed in pastoral land compared with unmodified land?

Q.13 Has the absolute level and availability of organic matter changed through farming practices? What has been and what will be the implications of these changes?

Q.14 How have other soil nutrient levels changed in comparison with land which has not been modified by man or rabbits?

We note with concern that there are no questions in this section on soil hydrology. We believe that moisture relationships of soil and the environment, and of soils and high country plants, are vital for sustainability. Note that we commented in the introduction that balance between inputs and outputs of basic resources like nutrients, energy and water is vital for any system which is to be sustainable in the long-term.

The appearance of many high country areas with expansive scree slopes, particularly in the greywacke zone, formerly led people to believe that erosion and mass movement was a serious problem. It is now known through historical dating techniques that, despite their appearance, such areas are relatively stable (Whitehouse, McSaveney and Chinn, 1980). Accelerated mass movement caused by excessive burning and grazing can occur and may be locally significant, but is relatively rare: the more insidious wind erosion effects are less obvious, more widespread, and harder to quantify.

It is easy to measure the extent of bare ground but that is not a measure of erosion, although it does influence the potential for erosion to occur. To measure erosion it is necessary to measure erosion rate or the transport of material by wind or water. Such measurements are not easy to make but with modern technology (isotopic tracer techniques), progress is being made (Landcare Research, *unpubl. data*). Indications to date are that wind is the most important agent of topsoil loss in the high country, and that wind erosion is more prevalent on sunny faces than on shady, more moist slopes.

There is a debate occurring within the scientific community as to whether *Hieracium pilosella* replaces existing vegetation, and hence is just a change in cover type, or whether it colonises ground that would otherwise be bare. This is fundamental to the whole *Hieracium*/degradation debate and more investigations are needed. It is, however, clear that the low growth habit of *Hieracium pilosella* reduces the wind zero plane height for turbulence, so that wind erosion potential can reach closer to the ground than under the previous tussock vegetation (Hunter, Mason and Robertson, 1992).

Water movement is likely to be more important in the wetter country than in the semi-arid zone (see comments in Background Information regarding frequency of high intensity rain in New Zealand). However, even in the wetter zone the occurrence of modern fans is not frequent. Water transport of nutrients in solution may be more important than particulate transport, but there is little evidence other than a study of the distribution of available P in soil at Tara Hills (AgResearch, *unpubl. data*).

Organic matter (humus) confers important properties on soil which are related to the fertility of productive soils, and are particularly important to ensure sustainability of both productive and unmodified soils. Such properties include water holding capacity, structural stability, source of mineralisable N, P, and S, and cation exchange capacity. It has been shown that, under grazing with no fertiliser inputs, the organic carbon content of soil can be reduced by up to 10% over 15 years (Landcare Research, *unpubl. data*). It has been shown that P supply from soil parent material (underlying rocks) could limit the amount of organic matter in soil and, if this limitation were relieved by P fertiliser, there would be an increase in soil organic matter (Walker, Thapa and Adams, 1959; Walker and Syers, 1976; Tate and Salcedo, 1988). Pasture improvement with fertilisers and grazing has led to a 66% increase in organic carbon (McIntosh *et al., in press*). On the other hand, in a trial at Tara Hills, with 3 levels of grazing intensity, there has been only minor (5 to 10%) change in organic matter over 15 years. The conclusion is that, although the principles are understood, the magnitude of changes will depend on local environmental and management conditions.

The following information is available on the semi-arid lands: measurable topsoil loss has occurred since the 1950s (Landcare Research, *unpubl. data*). "Degraded" lands often consist of a mosaic of areas with high potential for horticulture, and other areas with practically no potential (Hewitt, *in press*). Work on the Conroy land system has shown that tors and rocky bluffs are a refuge for many native species, and it is suggested that such refuge habitats are richer and more common in schist terrain than in greywacke country.

Studies on Conroy soils representing a "degradation" sequence show a range in organic matter content from 3.5%C under tussock to 1.5%C in a badly degraded site. Physical soil properties indicate that *c.* 2.5%C is the threshold below which soil structure is badly affected (Landcare Research, *unpubl. data*).

Reduction in organic matter levels in soils may have the effect of reducing water storage capacity of droughty soils and thereby further increasing their aridity. Measurements show this effect is small for Conroy soils, because degraded soils have vesicular pores which hold water, but the loss of the litter layer may be important in increasing drying, and reducing infiltration.

Application of the Rothamsted C-cycle model to the Conroy degradation sequence estimated 35 years as the minimum time needed for recovery of organic matter levels given nil grazing (Parshotam and Hewitt, *in press*). Given this indication of the likely time scale involved in a recovery programme, this information is of great significance for the high country.

Two series of studies have been conducted on soil biota in the tussock grasslands. The first of these (Thornton, 1958; and subsequent papers in this series) was designed to compare pastoral soils and unmodified soils. Unfortunately, this study does not provide the required information because the results were flawed by the sampling methods used. A more recent and comprehensive study of many aspects of a chronosequence of tussock grassland soils (Speir and Ross, 1981, and earlier papers in this series) gives data on soil biota and enzyme activities in soil, but does not provide the required comparison. What would next be valuable would be a comparative study of the soil biology and biochemistry of "native", "degraded" and "pastoral improved" soils.

In unmodified soils the levels of nutrients are determined by the soil forming factors and notably P depends upon the parent material, while S is more dependent upon climate and the atmospheric supply. N is closely related to organic matter content. Tussock grassland soils have a wide range in availability of P, from high in the driest Brown-grey earths, to low in the wettest and most strongly leached podzolised Yellow-brown earths. S is generally low in high country soils and is particularly low in the drier soils under the influence of the rain (and S) shadow to the east of the main divide. Fertiliser policies for pasture improvement are designed to overcome these natural deficiencies and allow the establishment of more demanding plants such as clover and other pasture legumes (Boswell and Floate, 1992). If successful, this policy leads to the build-up of soil N, which is commonly the greatest nutrient limitation on grass growth in both natural and improved soils. Nutrient levels in improved pasture soils therefore tend to be higher than in unmodified soils, but the actual levels depend upon how much and how often maintenance fertiliser has been applied. S is lost through leaching more readily than P, so when maintenance is neglected, S quickly becomes the limiting nutrient (Boswell and Floate, 1992).

It has also been shown recently in semi-arid areas dominated by rabbits that significant amounts of nutrients are isolated from the soil-plant system in the form of relatively stable, dried rabbit dung (Landcare Research, *unpubl. data*), and it is probable that nutrients are also immobilised for long periods in dry sheep dung.

General

Q.15 What are the parameters for sustainable land use in the high country? What management is required to avoid degradation?

Q.16 What indicators of sustainable land use should be monitored? How? Who should do the monitoring and who should pay? Are sufficient indicators currently being monitored?

The factors which determine the sustainability of any system of land use have to do with economic, social, efficiency and biophysical considerations. Because of our range of expertise we concentrate on the latter two as they apply in the high country.

Essential ingredients of sustainable systems are the balance of inputs and outputs of nutrients, energy and water. Closed systems may exist under natural conditions, but when cultural systems involve the harvesting of products, the efficient replenishment of the basic resources is a prerequisite for long-term sustainability. While it may be possible to postpone such replenishment to accommodate short-term economics, in the long-term, land use systems must be ecologically sustainable in order to be economically sustainable.

These considerations apply equally to the traditional pastoral use of the high country as to the possible use of the same lands for forestry or any other productive system. So long as these basic principles are understood and applied, we believe that it is appropriate to consider a much wider range of possible uses in the high country than has been entertained hitherto. These are likely to include pastoral systems, forestry, horticulture, viticulture and perhaps other land uses for production, together with activities such as adventure- and eco-tourism and other business enterprises which may assist with short-term economic sustainability, not in conflict with the sustainability of ecosystems, and traditional private recreation.

The aim of sustainable management should be to maintain biomass and primary productivity adequate to sustain the natural values and indigenous components and functional status of the ecosystem, and also retain soil and water conservation and water production potentials. This practical aim is consistent with the maintenance of balance between inputs and outputs of nutrients, energy, and water.

Most managed production ecosystems are currently operated under slightly acid soil pH conditions (typically pH 5.5 to 6.5), and one suggestion is to develop systems which operate under lower soil pH conditions (O'Connor has advocated for systems of "stable acid agriculture"). Just like any other system, these would have to fulfil the condition that inputs match outputs, but with the advantage that lower inputs might be required.

Some of the problems at the present time derive from a basic failure to replenish resources, but this is compounded by movements of those resources within systems. Where, for example, movement of nutrients occurs by grazing transfer (and concentration in localised areas) or by soil erosion or gravity, a maldistribution pattern of excess and deficiency develops. It is necessary to understand the processes and rates involved in order to try to devise ways and means of overcoming these problems.

In the introduction, under the heading "Some ecological concepts", we discussed the parameters which might be measured to monitor certain properties of ecosystems. The objectives of monitoring include the aim to find out if sustainability is being achieved. Because of the time scales involved it is often not possible to answer this until it is too late. Fundamental damage may be being done to ecosystems which show no appearance of harm unless the most sensitive, and appropriate, indicators are measured and interpreted correctly. The aim should therefore be to adopt a conservative approach at least until such sensitive indicators are available. Another aim is to provide early warning signals of impending damage.

There is also a strong case for land occupiers to monitor changes on their own properties. There would be benefits in this, both to the farmer and to the scientific community, but it also means that the techniques used must not only be suitable to record changes accurately and sensitively, but also be capable of being used by farmers. It is likely that a mix of methods will evolve with, for example, farmers keeping photographic records of vegetation and scientists measuring rate of erosion.

The properties which are most usually measured fall into the main groups of vegetation characteristics and soil properties. Soil parameters include depth, organic matter content and quality, moisture capacity, nutrient availability, and pH. In particular, a value of about 2.5% organic carbon is emerging as a threshold value indicative of severe depletion (Landcare Research, *unpubl. data*). Vegetation parameters include indicator plants, biomass, community structure, plant composition and ground cover. While it is important to measure such properties, and to accumulate records over time, we re-iterate here the important need to improve our ability to interpret that information in an integrated fashion.

All too frequently the soil data are collected and stored by one agency, while vegetation information may be held by a separate agency, and these agencies may not be aware of the other's data set. The challenge of interpretation includes the challenge to bring all the relevant information together in the most useful way. We suggest that modelling may be helpful in this regard and that whole system models which deal with relevant changes over time may be particularly useful. An example might be the Century model developed in Colorado which brings together soil data, N, S, and P-cycles, energy (C-cycle) flows and farm system data over 100 years. Based as it is on historical data, and validated with recent information, it is valuable in integrating all sorts of data and making predictions of likely future change. It has already been shown by Metherell (*pers. comm.*) that this model can be successfully applied to New Zealand pastoral systems. It may be capable of being extended to accommodate other relevant systems in the high country.

Some existing data sets which might be employed to integrate and interpret the high country systems include the following:

- Floristic sequences identified in PNA surveys (Espie *et al.,* 1984);
- Vegetation changes in historical plots (M. Treskonova and K. Connor, *pers. comms.*);
- Effects of fertilisers, irrigation and grazing at Mt John (AgResearch, *unpubl. data*);
- Rate of N loss under grazing (P. McIntosh, *unpubl. data*);
- Vegetation and soil data in relation to farm conditions at Tara Hills (AgResearch, *unpubl. data*).

Benchmark sites are important to establish reference points in time and space against which change can be recorded and measured. Records over time at one place can be used to interpret direction and rate of change, while records from different sites allow comparison of change under different ecological conditions. More benchmark sites are needed in the high country of large enough areas, both for scientific reference purposes and to monitor progress towards sustainability, as well as for nature conservation needs.

The height/frequency method appears to be well-suited to the assessment and long-term monitoring of biomass, biodiversity, structure, and plant cover in tussock ecosystems (Scott, 1965; Dickinson *et al.,* 1992), and could be useful in establishing a unified approach to the recording of representative coverage of the high country across institutions.

Most monitoring involves measuring static properties such as the size of nutrient pools. However, progress in interpretation will also demand a better understanding of ecological processes and the recognition that ecosystems are dynamic not static, which will need data on nutrient, energy, and water flow rates, under contrasting conditions of, for example, native tussock grassland, "improved" pastures, and "degraded" conditions.

With regard to the means of data collection, the Societies are committed to the participative approach which has recently evolved. We recognise the advantages of commitment and being able to access a store of local information not previously available to science. However, we also recognise the need for records to be relevant, regular and reliable. To this end, we would point out the need for national responsibility for audit and enforcement in record keeping.

Final Remarks

Finally, the Societies appreciate this opportunity to comment on the important questions related to the issues of South Island high country land management, and we would conclude by offering to be of further assistance in the development of sustainable policies for the high country.

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