AN ECONOMIC EVALUATION OF BIOLOGICAL CONTROL OF HIERACIUM

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AGRIBUSINESS & ECONOMICS RESEARCH UNIT

LINCOLN COLLEGE, CANTERBURY, NEW ZEALAND.

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PREFACE

With the increased emphasis on the economic aspects of scientific research, recognition of the usefulness of economic analysis as a means of evaluating some aspects of research programmes has become apparent. Research programmes often require substantial investments to be made in the anticipation of an uncertain outcome. For some programmes, possible outcomes can be identified. For such programmes, those outcomes can be evaluated in terms of their potential effect on the existing situation and the economic consequences of those outcomes. Economic analysis provides the tools to contribute to the evaluation of those outcomes. Uncertainty as to the actual outcome can be accommodated and the results of the analysis can provide useful guidance as to the potential economic consequences of the research programme.

The work reported in Research Reports 201 and 202 provides an example of the ways in which economic analysis can be used to evaluate research programmes which have highly uncertain outcomes. In these particular examples, the maximum potential benefit of a particular action is calculated. The uncertainty of achieving this outcome is assessed and probabilities attached to the achievement of less beneficial outcomes. Cash flows resulting from the potential benefits are adjusted by the probability of those benefits occurring to yield an expected cash flow. This cash flow can then be discounted to yield an expected net present value for the project. As information which alters the degree of uncertainty is obtained, then revisions to the probabilities can be made and new expected cash flows and expected net present values can be calculated.

This technique enables assessments of projects which have a range of potential outcomes and provides for the assessments to be updated as further information on the probability of particular outcomes becomes available. Projects which have been assessed on this basis can then be compared and better decisions made concerning the most appropriate allocation of scarce research resources.

Further work in this area is continuing in the Agribusiness and Economics Research Unit. An assessment of the "value" of the plant known as "Old Man's Beard" (Clematis vitalba) is being undertaken with a view to establishing the appropriate level of resources which could be assigned to control activities.

An evaluation of the economic benefits of a biological control programme was reported in Research Report number 200, which dealt with a review of the programme to control Rose-Grain Aphids.

While further development of the method reported in Research Reports 201 and 202 could be undertaken, this method provides a basis for the future evaluation of many scientific research programmes. Use of this method is recommended for such evaluation and can contribute significantly to a more informed distribution of scarce research resources.

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Assistant Director

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Dr David Scott, Grasslands Division, DSIR, provided invaluable information regarding the hieracium species found in New Zealand and the problems they pose in high country areas.

Chris Kerr of the Centre for Resource Management, Lincoln College, generously supplied data from high country production surveys to assist in the valuation of high country production.

Excellent typing support has been provided by Michelle Yen. An analysis such as this requires a number of assumptions to be made. The author must accept the responsibility for those finally used.

SUMMARY

This report presents the results of a cost-benefit analysis of biological control of hieracium. In South Island high country areas, species of the introduced hieracium genus are problem weeds. Mouse-ear hawkweed and king devil hawkweed are among two of the most abundant tussock grassland species in some areas of the South Island run country. These species exclude other plants and reduce feed availability, so causing a loss of agricultural production. They also exclude native grassland species and represent a threat to conservation values.

Biological control appears to be the only practicable control alternative for these weeds in many regions. It is estimated that hieracium species at present reduce the value of high country agricultural production by between $1.1 and $4.4 million annually. No attempt is made to value the cost imposed by the weeds to conservation values, although this cost is significant. Against these costs, hieracium species have negligible benefits.

The likely impact of biological control on hieracium species is uncertain. In order to estimate the benefits of biocontrol, a number of scenarios are developed. A decision theory approach is described which assigns probabilities to the outcomes of each scenario and determines a final net expected benefit for the proposed biocontrol project. This analysis suggests that under the assumptions used a biocontrol project would recover its costs about 14 years after release of control agents. The proposed project has an internal rate of return of 14.7% and yields an expected annual benefit of $205,000 once agents are assumed to be fully established.

The analytical framework presented provides a useful tool for further analysis of the assumptions used and the issues involved in biological control.

CHAPTER 1

INTRODUCTION

Species of the introduced hieracium genus, are problem weeds that are a source of concern in South Island high country areas. Two hieracium species, mouse-ear and king devil, are among the most abundant tussock grassland species in moderate and low rainfall areas of the South Island run country (Scott 1984). Although they are eaten by stock, these species are regarded as weeds because they exclude other plants and reduce the total amount of feed available. They are also common in some national parks and scenic reserves where they may be detracting from the scenic value of these areas.

Hieracium species have proved resistant to most herbicides, so that chemical control of the weeds does not appear practical. The main method of control at present is to develop land by application of fertiliser and oversowing with pasture species. This has been found to successfully suppress hieracium on moderately fertile soils. However, Scott (1984) notes that on unfertilised or poor sites there appear to be no effective options for hieracium control at present.

The hieracium species causing problems in New Zealand are natives of Europe. The same and other species have also been of concern as introduced weeds in North America and Japan. In their native environment they are not seen as causing significant weed problems. One possibility is that there may be some biological agents present in Europe which effectively control the weed. Biological control of the weeds offers an attractive control option, if it is possible. Biocontrol could provide a long-term solution to the problems caused by the weeds for agriculture and is the only means known which could be used in reserve areas.

The Department of Scientific and Industrial Research (DSIR) is currently considering the biological control of hieracium . However, a biological control programme is a potentially costly exercise. Suitable agents must be identified, screened for any adverse effects, introduced to New Zealand and then released and monitored. It is desirable to identify the present economic costs of hieracium to New Zealand before embarking on such a programme. Cost-benefit analysis is the logical conceptual framework within which to carry out an evaluation of this nature. This report describes the results of a cost-benefit analysis of biocontrol of hieracium carried out on behalf of the High Country section of Federated Farmers and DSIR.

A number of cost-benefit analyses of biocontrol projects have been carried out in the past, the most notable in New Zealand being that by Sandrey (1985) who examined the biological control of gorse. Cost-benefit analysis essentially consists of enumerating the potential costs and benefits of a possible course of action, and where possible quantifying these costs and benefits.

The major cost of hieracium to New Zealand agriculture is the opportunity cost of production lost due to the weeds, through their exclusion of other pasture plants. Chapter 3 discusses these and other costs. Against these costs must be balanced any benefits the weeds provide; chapter 4 discusses them. Chapter 5 evaluates the likely impact of biocontrol agents on the weeds and examines the costs and benefits of a biological control programme in the light of this impact. This information allows decision makers to determine whether or not biological control is justified on economic grounds. It may also permit the proposed biocontrol for hieracium to be ranked in relation to similar projects for other weeds.

CHAPTER 2

DISTRIBUTION AND PROBLEM STATUS OF HIERACIUM

Hieracium (genus *Hieracium*), are considered to be important weed species in the South Island high country. Two distinct types of the weed exist. Some are single stemmed (sub genus *Hieracium*) of which many thousands of species are found in the northern hemisphere. The second type is usually perennial, and reproduces by both vegetative mat forming runners and seed. This second type was originally confined to Europe and consists of about 60 species referred to as a separate sub genus *Pilosella*. It is members of this second group which have created the most problems as weeds when introduced to other cool parts of the world, with USA, Canada, Japan and Patagonia all recording problems with these species as well as New Zealand. At present there are 5 species of each type in New Zealand. Details of each are presented in Table 1.

The approximate order of weed status of these plants in New Zealand is : mouse-ear hawkweed; king devil; field hawkweed; single stemmed hieracium species; orange hawkweed (D. Scott pers comm.)

Mouse-ear hawkweed is at present regarded as a major weed of the lower fertility extensively grazed areas of South Island run country. It is most prevalent in the moderate to mid rainfall zone (500-700mm) but is present also in higher rainfall areas and to higher altitudes. The plant has been present in New Zealand for some time - last century it was a problem on the South and Mid Canterbury lowlands. In the 1920s, it was recorded in the adjacent hill country. It expanded rapidly in the high country in the 1950's. This expansion may have been linked to rabbit control and a series of warm wet summers. Whatever the cause, the plant found a niche in the high country. Mouse-ear is regarded as a weed because its competitiveness excludes other plants and its low mat-forming growth reduces the total feed supply available to stock. Experiments have shown that it is a component of stock diet. While it can be controlled on better soils by fertilising and over-sowing it remains a problem on areas incapable of economic development and retired land, reserves and national parks.

King devil and field hawkweed are of little concern on heavily grazed land. But they can invade lightly grazed land and they may become dominant, excluding other species

Table 1
New Zealand Hieracium Species

(A) Mat Forming Species

1. Hieracium pilosella or mouse-ear hawkweed
Present in Canterbury since last century and now in both islands from sea level to 1500m, reaching its greatest density in pastoral run country of the South Island.

2. H.praealtum or king devil
Present in the mid-altitude regions of Nelson, Marlborough, Canterbury, Westland and Otago.

3. H.pratense or field hawkweed
Similar regions but generally higher altitudes than king devil.

4. H. x stoloniforum
Adventive in Taranaki, Wellington, Marlborough, Canterbury, Westland and Otago.

5. H.aurantiacum or orange hawkweed
A minor horticultural plant and adventive in Manawatu, Nelson, Canterbury and Westland.

(B) Single Stemed Species

1. H. sabaudum
2. H. pollichiae
3. H. lepidulum
4. H. murorum
5. H. argillaceum

Source: Flora of New Zealand Vol. IV

on retired land. King devil is more prevalent on drier, lower altitude lands while field hawkweed is more prevalent in higher altitude and wetter areas.

Orange hawkweed at present is not a problem weed in New Zealand. In other countries, however, it is this species which has caused problems. In Japan it is considered a major weed (Suzuki and Narayama 1977). The same is the case in parts of North America (Thomas and Dale 1974, 1975, 1976; Vander Kloet 1978). Orange hawkweed is also used as a rock garden plant.

The single stemmed hieracium species are mainly found along the mid altitute grassland/shrubland/forest boundary. These weeds are of minor importance to agriculture but may cause concerns in forest reserves and national park areas.

The distribution patterns presented in Table 1 and discussed above give only a general idea of the areas affected by hieracium. In the MacKenzie Basin hieracium may cover up to two thirds of the area of drier ground (G.Kerr pers comm). Unfortunately, little data is available upon which to base more accurate assessments of the areas involved.

Bascand and Jowett (1981, 1982) reported surveys of scrubweed distribution and problem status in the South Island. In surveying the managerial problem status of scrubweeds a number of herbaceous weeds were also found to be a problem, hieracium among them. Hieracium species were ranked ninth as serious problem weeds in the South Island, being rated as a serious problem on about 6.5% of the blocks of farmable land covered by the survey. This compared to 38.8% and 34.3% for barley grass and gorse respectively, the two most serious problem weeds. Unfortunately, the Bascand and Jowett surveys do not enable the determination of the percentage of farmable land covered by hieracium as distinct from the percentage of farmable land in which they are present. Hieracium was found to be of most concern in Canterbury and Otago, and to a lesser extent, Marlborough. Bascand and Jowett (1982) noted that "The only pastoral weeds not listed by previous writers as potentially serious and considered now to have achieved problem status are hieracium...". The relatively recent arrival of hieracium in high country areas has previously been noted. The weeds may still be spreading, so that to the problems currently posed must be added future potential problems.

The Bascand and Jowett surveys covered all South Island agricultural and pastoral land below 1220m. Since hieracium is principally a problem in high country areas the discussion and analysis which follows focuses on these areas and ignores any weed problems in other areas. In a survey of high country farmers, Kerr and Lefever (1984) found that hieracium ranked fourth equal with gorse as weeds of major economic significance (Table 2). There seems to be a clear perception of hieracium as weeds of significant economic importance in the South Island high country.

Earlier surveys of high country farms (Graham 1979) found hieracium to be widespread, and rated second only to briar in frequency as "in excess". Table 3 shows hieracium distribution by county in 1976/77. Hieracium was found to be "in excess" on 33 (11 percent) of high country properties in the survey.

Table 2
Weeds of Major Economic Significance
1982 Survey of High Country Farms

	% of 207 Runs Reporting Weeds of Concern	% of All 250 Runs Responding
Brier	52	43
Matagouri	34	28
Broom	29	24
Hieracium	25	20
Gorse	25	20
Nodding Thistle	9	8
Barley Grass	7	6
Bracken Fern	4	4
Burdock	4	3
Thyme	4	3
Manuka	4	3
Tutu	4	2
Other weeds	9	8

Source: Kerr and Lefever (1984)

Table 3
Hieracium Distribution by County
in the High Country 1976/77

No. of Properties	County	Excess	Occurrence	%
19	Marlborough	2	10	53
3	Kaikoura	1	2	67
8	Amuri	-	2	25
5	Hurunui	-	1	20
3	Oxford	-	2	67
15	Malvern	-	7	47
15	Ashburton	2	8	53
38	MacKenzie	13	31	82
3	Strathallen	-	1	33
5	Waimate	2	5	100
50	Waitaki	5	32	64
54	Vincent	6	17	31
24	Maniototo	1	12	50
45	Lake	1	5	11
3	Tuapeka	-	-	-
10	Southland	-	1	10
Total 300		33(11%)	136	45

Source: Graham 1979

When the same results are considered in terms of the climatic classification used in Tussock Grasslands and Mountain Lands Institute surveys the results are as shown in Table 4. The areas of greatest concern for both "excess" and "occurrence" were Marlborough Moist, Canterbury Moist and Otago Moist. This confirms the belief that hieracium species are of greatest concern in intermediate rainfall areas rather than in extremely wet or extremely dry regions. Graham (1979) notes further that "...it appears that perception of these weed species is somewhat more widespread in Marlborough and Canterbury than in areas to the south. Whether their actual incidence is less in the south is not known with certainty."

Table 4
Hieracium Distribution by Climatic Regions
in the High Country, 1976/77

No. of Properties	Area	No. of Properties Reporting Excess	Occurrence	% Occurrence
23	Marlborough Moist	3	15	65
51	Canterbury Moist	11	33	65
36	Canterbury Wet	3	18	50
46	Otago Dry	4	18	39
91	Otago Moist	10	43	47
36	Otago Wet	2	8	22
17	Southland Moist	-	1	6
Total 300		33	136	45

Source: Graham 1979

CHAPTER 3

CONTROL AND COSTS OF HIERACIUM

In order to evaluate the biological control of hieracium it is necessary to establish what the current and, if possible, future costs of the weeds to the nation are. The most significant economic impact of the weeds is in loss of production. Estimates of the value of this lost production are presented in Section 3.2 below. However a number of methods for controlling hieracium have been suggested and these are discussed in the following section along with the possible costs these impose, where appropriate.

3.1 Alternative Methods of Control

Some research has been conducted into control of hieracium. A number of possible control methods have been suggested. The major alternatives discussed below are grazing, chemical control, pasture development, competitive plant species and biological control. One of the major concerns raised by hieracium, however, is that to date no control method has proved successful on much of the land infested.

3.1.1 Grazing

Scott et al (1985) investigated the effect of grazing on mouse-ear hawkweed. Mouse-ear is adapted to grazing by its low mat forming habit. Trials indicated that it is not controlled by mob or set stock grazing at any time of the year. In fact, grazing may even stimulate the spread of the weed. Makepeace (1980) has shown that less than 1% of plants establish by seed, with vegetative growth accounting for over 99% of spread. Sheep have been shown to actively select flowers of mouse-ear (Hughes 1975, Scott and Mansell 1974), but removal of the flowers only serves to promote vegetative spread. The present advice is that there is probably a greater depletion of reproductive potential by not grazing during flowering (D. Scott pers. comm.).

The effect of grazing on other hieracium species is less clear. King devil and field hawkweed are not common on land which has regular annual grazing. Once present their spread can be slowed, but not stopped, by grazing, while in the absence of grazing these plants increase rapidly.

Grazing, if effective, would be a very attractive control method economically, as it is effectively costless. However, it appears that grazing is generally ineffective as a control method, although it may slow the spread of some hieracium.

3.1.2 Chemical Control

Some investigations of chemicals which might control hieracium have been carried out. Mouse-ear hawkweed is resistant to most chemicals (Matthews 1975). Meeklah (1979) found that the best herbicides for control of mouse-ear hawkweed were 2,4D ester at 1 to 2 kg/ha or a mecoprop/ MCPA/diacamba formulation at 1.5 to 3 kg/ha. Variable results were obtained, but the best time of year for application was October to December.

A problem with chemical control is that the chemicals have as much, or more, impact on many desirable pasture species as they do on hieracium. Chemical treatment is also expensive. Using costs in the 1988 Lincoln College Farm Budget Manual, the two chemicals at rates suggested by Meeklah would cost $30 to $50 per hectare for 2,4D ester and $50 to $100 per hectare for the mecoprop mixture. This excludes application costs, which would be of the order of $100 to $150 per hectare for aerial spraying. Total kill is unlikely, with 80-95 percent kill at best, and follow up with fertiliser and top dressing would be considered essential.

Chemical control of hieracium is not currently considered an economic possibility, at least on a large scale. Farmers are unlikely to use chemical control at present (D.Scott pers. comm.) on any hieracium - it is simply uneconomic.

3.1.3 Pasture Development

The only effective control method found to date for mouse-ear hawkweed is to apply fertiliser and oversow or overdrill infested land with pasture species. Alsike clover, in particular, has been found to compete successfully with hieracium. Scott (1984) and Cossens and Brash (1980) have investigated control of hieracium by pasture development. On moderate fertility sites it was found that clovers became dominant within one to two years and that mouse-ear almost disappeared after four to five years. On lower production sites, pasture development is less effective and the process takes much longer. Scott et. al found that control was only achieved on patches of deeper soil, with hieracium still increasing on poorer soils. Scott (1984) states "there are at present no demonstrated options for mouse-ear control on unfertilised or poor sites....".

The objective of agricultural development is to provide feed for stock, rather than to control hieracium. Farm managers will have to make decisions regarding land development based on the expected returns from the resources used. The research available to date indicates that greater returns from fertiliser and seed applications can be expected from the more fertile soils, and that development of marginal soils may not be economic. Pasture development, therefore, while it can offer control of hieracium under some conditions does not offer a final solution to the problem. It is therefore not possible to estimate the current levels of expenditure on land development specifically aimed at hieracium control. Some estimates of cost entailed can be made though.

3.1.4 Competitive Plants

Scott (1984) discusses the possibility of controlling hieracium at existing soil fertility levels by sowing competitive plant species. He emphasises the distinction between plants which are adapted to survive in a similar environment to hieracium with species that have attributes giving them specific competitive advantages over hieracium. To date, only one species has been found with a positive competitive ability - alsike clover. This is probably due to alsike's taller growth over shadowing mouse-ear. While similar competitive species may be found, Scott (pers. comm.) believes that the competitive advantage will still be small. The success of pasture species with fertiliser is interpreted as a change in species suitability with the change in environment, rather than competition.

Sowing and management costs are involved in introducing competitive plants. This option is essentially little different from that of land development, except that, if suitable species are found, fertiliser may not be required.

3.1.5 Biological Control

While the alternative control methods previously discussed may be practical on agricultural land under some circumstances, they cannot be used in national parks or scenic and other reserves. Moreover, options such as land development or sowing of competitive plant species are effectively farm investment decisions rather than simple control methods for hieracium.

Biological control of hieracium, if possible, offers an attractive alternative control method. It is a long term option, both in terms of establishing effective biological control agents and in terms of the control achieved. This contrasts with, say, land development, where further application of fertiliser and seed are likely to be necessary from time to time. On the other hand, the effectiveness of biological control is open to question. The fact that hieracium species are not a weed problem in their native environment suggests that there may be a biological agent at work. However, the search for such an agent can be a long and costly exercise.

Some possible candidates obtained from an initial literature search are listed in Scott (1984), although no work has been done to determine their suitability for introduction to New Zealand. Identifying, introducing and successfully establishing an agent or agents is likely to cost in the region of $1 million. The prospects for biological control are discussed further and in greater detail in Chapter 5.

3.2 Costs of Lost Production

Hieracium plants exclude other pasture species and reduce the amount of feed available for stock. They therefore reduce the productive potential of infested land. This imposes opportunity costs on farmers and the nation through production losses.

Appendix A contains an estimate of the value of high country production, based on the New Zealand Meat and Wool Boards' Economic Service (NZMWBES) Annual Sheep and Beef Farm Survey data, and MAF product price assumptions. This gives a value of about $84 million for high country production at 1986-87 levels in 1988 dollars. It can be seen that if hieracium reduces overall production by only one or two percent, this amounts to almost $1 million annually. In fact, estimates given in Scott (1984) suggest that hieracium may cause production to drop by 15 percent on improved land and 5 percent on unimproved land. Very dry and very wet areas where hieracium do not flourish may suffer little or no loss. However, on some runs hieracium may reduce production by up to 30 percent (Scott pers comm). Intermediate rainfall areas are likely to be worst affected. The total value of production from the three moist (intermediate rainfall) regions (Marlborough, Canterbury and Otago Moist according to the TGMLI classification) was estimated to be nearly $42 million (see Appendix A).

Estimates in Scott (1984) suggest that high country production can be apportioned 54% to improved land, 30% to land which is capable of improvement but has not yet been improved and 16% to areas unlikely to be improved using known technology. These estimates refer to animal feed production, not to land area - most high country land would come under the `unimproved' category. Assuming the estimates to be correct, production losses of 15% on improved land and 5% on unimproved land in the three moist regions would be valued at approximately $4.4 million annually in 1988 dollars. If losses of a greater magnitude, say 30% on improved land and 10% on unimproved land, were assumed, the total cost would be $8.7 million per annum. Even a reduction of only 5% in production from improved land in the moist areas would cost $1.1 million. Ignoring the effects of hieracium in other regions, $1.1 to $4.4 million appears to be a plausible and fairly conservative estimate of the range of costs of hieracium to the nation at current levels of production.

While little quantitative data is available on the extent of hieracium species, there seems to be a common impression that they are still spreading. Hieracium is presently more prevalent in drier regions but the growth rate measurements of Makepeace (1980) suggest that ultimately it may become more prevalent in the moderate 600-800mm rainfall zone. It is therefore possible that future production losses will be greater than those experienced currently. Moreover, this assessment has considered only the impact on high country production. Hieracium also affects South Island hill country areas, although it is perceived as mainly a high country problem.

3.3 Other Costs of Hieracium

On productive agricultural land, or potentially productive land, the costs of hieracium can be measured in terms of production lost. This may be a difficult figure to quantify, but at least it is a soundly based measure of the cost of the weed. In areas such as national parks or reserves, however, the cost of weeds is much more difficult to assess. Such land has no productive value, at least for agricultural purposes. The cost of the weed in these areas is in some measure of intangible 'scenic resources'. While techniques exist to estimate the value of such non-market resources, and the cost of the weed, they are beyond the scope of this study.

The extent of the problem is also difficult to measure. Hieracium species compete with native plants and may thus be endangering some native species. The Department of Conservation (D.O.C.) recognises hieracium as a threat to conservation values and agricultural values in the high country through displacement of native vegetation. However, grasslands are under-represented in reserve areas at present so that not much reserve land administered by D.O.C. is in the risk areas (C.Baddeley pers. comm). Perhaps the best that can be said is that there is a significant cost associated with the presence of hieracium in these areas.

Some farmers believe hieracium have a direct adverse reaction on sheep (Scott pers. comm.) Some claims have also been made that hieracium cause problems for water conservation. Hieracium may:

i) decrease interception
ii) increase run-off
iii) increase winter snow avalanching

However, Scott (pers. comm.) knows of no data to support these claims. Hieracium is generally more prevalent on the mid to low rainfall regions of more gentle topography where these problems are of less concern. Table 5 summarises the costs of hieracium discussed above.

Table 5
Summary of the Costs of Hieracium

Lost production	$1.1 to $4.4 million p.a.
Stock health	
Water and soil conservation	
Loss of scenic values in national parks and other reserves	
Threat to native plants	
Loss of conservation values and species within agricultural areas	

CHAPTER 4

BENEFITS OF HIERACIUM

The introduced hieracium species in New Zealand have come to be regarded as problem weeds, particularly in the South Island high country. However, some limited benefits may be obtained from the plants.

In the past, mouse-ear hawkweed was one of the commercial sources of the chemical umbelliferone, which can be used as a chemical marker and is one treatment for brucellosis in cattle (Greib and Duquensis 1954, Meylaender et. al. 1968, Quarante 1970). There is little prospect of similar use in New Zealand, and certainly no proposal to do so. The chemical is present in other plant extracts and now produced synthetically.

While they do exclude other, more productive pasture plants, hieracium may still be eaten by stock, so they are of some benefit as a source of stock food. This ignores any potential negative effects on stock health from eating the plants. Hieracium may also exclude other undesirable weeds. There is some evidence that mouse-ear suppresses growth of sweet briar.

There is a possibility that hieracium species may be of benefit in soil conservation as they do provide ground cover on what could otherwise be bare ground. Plant establishment studies have shown that plant cover of any form, including hieracium, is a superior seed bed for surface sown seed than bare soil. This is because of the high incidence of spring needle ice formation on bare soil wrenching seedlings from the soil. The impression is that hieracium in general only replaces existing ground cover and only to a minor extent invades previously bare ground. This expansion into bare ground maybe more prevalent for the hieracium species other than mouse-ear. There is an impression that mouse-ear can actually increase bare ground, as indicated by the frequency of patches with a halo of bare soil around often dead centres (Scott pers comm).

The orange hieracium has been used as a rock garden plant and so has some horticultural use. Other related species may be used similarly, although mouse-ear and king devil are not. This is a very minor benefit, but does have some positive value.

Mouse-ear and other hieracium species may be a honey source. Some initial work indicates that hieracium may be a relatively important source of pollen in Spring in the Craigieburn area (D.Pearson pers comm). Bees have been observed to collect pollen from hieracium species in the area and an analysis of November pollen suggests a large proportion is from Taraxicum type plants. This is an important time of year when pollen is in demand in order to build up hives. A large number of other pollen sources were also recorded in the area, however. In a pollen analysis of New Zealand honey, Moar (1985) found that Taraxicum type plants, which include hieracium, did not exceed 1% in honey from hieracium areas. Hieracium overall are therefore only of very small benefit to honey production, although possibly locally important in some regions.

There is a small market for mouse-ear hawkweed seed for herbal purposes. This amounts to about 10 kilograms of seed annually and could be maintained from a specialised crop area.

Table 6 summarises the benefits discussed above. None of these benefits is quantified, and none appear to be either significant or large. However, they do need to be mentioned if only for completeness in any cost-benefit analysis.

Table 6
Summary of the Benefits of the Hieracium

Source of umbelliferone
Food source for stock
Soil conservation
Horticultural (rock garden) plants
Pollen source for honey production
Suppression of other weeds
Seed for herbal purposes

CHAPTER 5

IMPACT, COSTS AND BENEFITS OF BIOCONTROL OF HIERACIUM

5.1 Probable Impact of Biocontrol

Biological control has been suggested as a possible means of controlling hieracium in New Zealand. As noted in the introduction, a biological control programme may prove to be a costly exercise. Prior to commencing such a programme it is advisable to conduct an assessment of the costs of the weed. Harris (1980) notes that "All too often biocontrol is started with little or no knowledge of the losses from the target weed...". He cites the case of galvanised burr (Bassia birchii) in Australia; Legislation requires control of the weed but the losses are too small to make control economic. Evaluations of weed control projects which have been made include Cullen (1978), Hartley and James (1979), Vere et al (1980) and Sandrey (1985).

In evaluating biocontrol of weeds, additional difficulties arise because of the uncertainties regarding establishment and effectiveness of the biocontrol agents. Even where biocontrol is found to be the least cost method of control from a social standpoint, Tisdell et al (1984) argue that institutional, social and economic arrangements may constrain its use.

Hieracium species occur naturally in Europe and the northern hemisphere where they are not regarded as serious weeds and seldom occur in the density seen in New Zealand. However, when introduced into other countries they have caused problems. Biological agents not present in these countries may be responsible for controlling the plants in their native environment. The aim of biological control is to regulate the growth of hieracium control and spread through the introduction to New Zealand of insects or other organisms which limit the plants growth in their native environment. Scott (1984) lists a number of possible candidates for biocontrol and has since investigated two fungi which offer some promise. Possible biocontrol agents are listed in Table 7.

The suitability of the two fungi for introduction to New Zealand has been investigated by D. Scott (pers. comm.). Based on field observations in Europe and glasshouse experiments conducted in Edinburgh he found that the rust could slow growth rates of mouse-ear hawkweed by about 2.7% and the powdery mildew could slow growth by 2-12%.

In addition to these points, there may be little or no research indicating exactly what the impact of the agents is on the weeds in their native setting.

Table 7
Potential Agents for Biocontrol of Hieracium in New Zealand

Insects:	
Celypha capreolana	- Mining in the roots.
Oxyptilis ericetorum	- In central bud of rosette.
O. parvidae	- In leaves and central bud of rosette.
O. pilosellae	- In central bud and root-crown of H.pillosella, apparently monospecific.
O.tristi	- Central bud and between leafbase and shoot.
Aulacida sp.	- Galls on central shoot and stolons.
Aulacida pilosellae	- Galls on petiole and central vein of leaf.
Aceria pilosellae	- Causing galls along leaf margin and on leaf blade.
Cystiphora pilosellae	- Blister galls on leaves.
Cerosipha pilosella	- On shoot base and stolons.
Dactynotus pilosellae	- On flower shoots and stolons.
Nasonovia pilosellae	- On flower shoots and leaves.
Heterostylodes nominabilis	- In flower heads.
Cochylis atricapitata	- 2 generations: 1st in flowers and shoots, 2nd in central bud of rosettes.
Contarinia pilosellae	- In flower heads (2 generations).
Tephiritis ruralis	- In flower heads.
Fungi:	
Puccinia hieracii var. piloselloidarum	- Rust.
Erysiphe cichoracearum	- Powdery mildew.

Source: Scott (1984)

Experience with biocontrol projects has shown that long term control of weed problems is possible. Julien et al (1983) examined attempts at biocontrol of weeds made prior to 1980. Of those examined, 39% were deemed to be successful in that some level of control was achieved. It is very difficult to predict the impact of biocontrol agents, however. Sandrey (1985) mentions a number of factors which may cause prediction problems:

- Establishment and dispersal of control agents in New Zealand in the absence of natural enemies.
- Population responses of control agents in New Zealand in the absence of natural enemies.
- Impact of native predators and parasites on control agents.
- Response of other plant competitors to weakened hieracium.
- Impact of climate on control agents.

For these reasons it is not possible to predict with any certainty the impact biocontrol would have on hieracium. In determining the benefits of biocontrol (in Section 5.3) possible scenarios of biocontrol impact are used. For the purposes of this study, the following three impact scenarios are considered:

(i) Low Impact Scenario: The biocontrol agents establish over a period of time but have only minor impact on hieracium. Mouse-ear is still a problem under this scenario, with vigour being reduced slightly. In terms of agricultural production, only 1-5% of the potential for increased production is achieved.

(ii) Medium Impact Scenario: Under the medium impact scenario the agents are more successful. Spread of hieracium is controlled and significant reduction in vigour of some plants occurs. Plants grow and spread more slowly. Hieracium species are much less a problem on developed land and also less extensive on undeveloped land. 15-25% of the potential increase in agricultural production is achieved.

(iii) High Impact Scenario: The high impact scenario sees hieracium affected to such an extent that on developable land they are no longer a serious weed problem. They may still cause problems in some undeveloped areas but are generally far more scattered and less dense. Ground cover of hieracium is nowhere greater than about 10 to 20 percent. 50-75% of the potential for increased agricultural production can be realised.

It should be remembered that these scenarios are not necessarily mutually exclusive, and that they by no means exhaust the possible impact scenarios. They are designed simply to give a basis for evaluating the benefits of biocontrol, discussed later in section 5.3. They do not rely, either, on data relating to any specific agent - for instance, that supplied by Scott regarding fungi - but are based purely on hypothetical levels of control achieved by an unspecified biological agent.

Given the past history of biological control projects there is a moderate probability of some level of control being achieved. The implications of these scenarios and the uncertainty regarding the outcome of biocontrol are explored further in Section 5.3. There is also uncertainty regarding the time frame of a biocontrol project. Biological agents may take several years to establish in New Zealand at levels sufficient to have any significant economic impact on hieracium species. Immediate impact following release of agents is most unlikely. Instead, the impact of introduced agents is likely to rise gradually over a number of years until the full impact potential of the agents is reached.

How long this process might take is difficult to predict, but it is probably of the order of at least five to ten years. The lead time involved can be influenced by the resources put into rearing agents prior to release, and by chance climatic and environmental factors after release. Section 5.3 explores the impact of this lead time on the potential benefits obtained from biocontrol in more detail.

5.2 Costs of Biocontrol

Hieracium species have few significant beneficial qualities, as discussed in Chapter 4. This contrasts with gorse where Sandrey (1985) had to take account of the value of gorse to beekeepers as a pollen source. Effective

Table 8
Possible Costs of a Biocontrol Project
Assuming Two Agents Involved

Year 1	CIBC	Host-testing	$ 40,000
Year 2	CIBC	Host-testing	$ 40,000
Year 3	CIBC	Host-testing and shipment	$ 40,000
	DSIR	Research in quarantine (0.25 scientist year, 0.25 technician year)	$ 50,000
Year 4	DSIR	Quarantine completion first releases (1 scientist year, 1 technician year)	$200,000
Year 5	DSIR	Rearing and release (0.5 scientist year 1 technician year)	$140,000
Year 6	DSIR	Assessment (0.5 scientist year, 1 technician year)	$140,000
			$650,000

Source: R. Hill pers comm.

biocontrol of hieracium would reduce the benefits the species provide, so imposing a cost on the nation. This cost is not easily quantified but since the benefits of the plants were judged to be minor, only a small cost is possible. The most significant cost would appear to be the small reduction in pollen source in some areas.

The major cost of biocontrol is thus the cost of the research required to identify suitable control agents and to successfully introduce and establish them in New Zealand. Biocontrol projects are by their nature long term and may involve several years of research and monitoring. The full costs of biocontrol could be in the region of $1 million, or even higher. Table 8 presents the estimated costs of a biocontrol project involving two agents and taking six years. As shown in the table, such a project would cost $650,000, in 1989 dollars. This is only one scenario, and it is quite likely that a project for hieracium could cost more. The major costs involved are salary costs, with the costs of a scientist for a year estimated to be $120,000 and a technician $80,000 in 1989 dollars, allowing for salaries and overheads.

A further potential cost of biocontrol is related to the possibility that biocontrol agents may not be completely host-specific. Some native species related to the problem hieracium species may be at risk. The fungi considered for introduction were found to affect some native species under some conditions. However the introduced hieracium themselves are thought to be a greater threat to native plants (Scott pers comm). The potential impact on non-target species is as difficult to predict as the impact on target species. The main concerns appear to involve closely related plants which are under pressure from hieracium in any case. It is unlikely that any non-specific agent would even be considered for introduction, and the chances of any significant costs from this source are remote. Testing to eliminate unsuitable agents on these grounds is part of a biocontrol project.

The only quantifiable cost of biocontrol, then, is the cost of the biocontrol programme itself estimated at about $650,000 but which could be up to $1 million over an extended time period. Some other costs have also been mentioned, but these are believed to be minor and of relatively low significance. Additional, non-market type, factors associated with biocontrol are:

- The irreversible nature of introduction.
- Replacement of hieracium by other weeds.
- Elasticity effects of increased production.
- Reduction in habitat for other biota.

5.3 Benefits of Biocontrol

Chapter 3 discussed and to a limited extent quantified the costs imposed on the New Zealand agricultural sector by hieracium species. Opportunity costs of lost production were estimated for South Island high country farms. The costs of current control measures were also discussed but it was not possible to derive an overall estimate of these costs. It was estimated that annually hieracium species cost the nation between $1.1 million and $4.4 million in lost agricultural production.

The likely impact of biocontrol on hieracium was examined in section 5.1. As discussed there, it is not possible to determine the impact of biocontrol in advance, with any degree of certainty. Three possible scenarios were suggested. In Table 9 the annual benefits of each scenario, in economic terms, are presented, based on the assumptions underlying the scenarios. The actual monetary (and other) benefits of biocontrol are likely to be intermediate between these scenarios, and will very likely vary from region to region. However, the range of benefits identified provides some sensitivity testing of the results, and gives a broad range of likely benefits. This provides a basis for determining whether or not to proceed with research into biocontrol of hieracium.

Table 9
Potential Annual Benefits of Biocontrol of Hieracium

Scenario	Assumed Cost of Hieracium $1.1Million	$2.5Million	$4.4Million
Low Impact (1% - 5%)	$11,000 to $55,000	$25,000 to $125,000	$44,000 to $220,000
Medium Impact (15% - 25%)	$165,000 to $275,000	$375,000 to $625,000	$660,000 to $1.1M
High Impact (50% - 75%)	$550,000 to $825,000	$1.25M to $1.88M	$2.2M to $3.3M

Biocontrol also offers a number of additional benefits which cannot be readily quantified. These are listed in Table 10.

Table 10
Additional Benefits of Biocontrol of Hieracium

* Environmental or non-market values are enhanced- biocontrol is the only potential control option in national parks and scenic reserves.
* Some form of control is possible on undeveloped agricultural land where land development is uneconomic.
* Employment multiplier effects from increased production.
* Contribution to science from the experience.

On their own the potential annual benefits in Table 9 provide little guidance as to the desirability of introducing biological control for hieracium. To properly evaluate a proposed biocontrol project account must be taken of the costs involved and the likelihood of success. Simply looking at the possible benefits presented in Table 9 is misleading unless these are weighted in some way by the probability of them being attained. For instance, a benefit of $2 million annually is very attractive and would clearly justify a high level of control expenditure on economic grounds. However, the chances of such a high benefit level being achieved are small. It is more likely that no benefit at all would be achieved if the 39% success rate for biocontrol projects reported by Julien et al (1984) is taken as a guide.

The following analysis illustrates how a decision theory type approach provides a useful method for explicitly taking the uncertainties involved in biocontrol into account. Using the approach described below, it is possible to derive a single expected benefit figure for a proposed biocontrol programme.

The first step is to enumerate the possible outcomes of the project and to assign probabilities to those outcomes. For the purposes of this discussion, the potential low, medium and high benefits presented in Section 5.1 are used together with possible zero, five and ten year lead time periods for agents to establish full impact following release.

Table 11
Summary of Probabilities Assumed

Level of Impact ($ Per Annum)	Lead Time Period From Release to Full Impact			Total Probability
	0 Years	5 Years	10 Years	
Nil ($0)	0.025	0.175	0.3	0.50
Low ($20,000)	0.0125	0.0875	0.15	0.25
Medium ($500,000)	0.01	0.07	0.12	0.20
High ($2Million)	0.0025	0.0175	0.03	0.05
Total Probability	0.050	0.35	0.60	1.00

As indicated in Table 11, it has been assumed that there is a 50 percent probability that the benefit from introduction of a biocontrol agent will be "nil". This figure assumes a higher chance of success than found in past biocontrol projects (39% referred to earlier) allowing for some scientific and technological advances in biocontrol but still reflecting the high level of uncertainty involved. There is a 25 percent probability that the benefit will be "low", a 20 percent probability that the benefit will be "medium" and 5 percent probability that the benefit will be "high". Probabilities have also been assigned to the likelihood of the full impact of biocontrol being achieved in zero years (i.e. immediately)(five percent), five years (30 percent) and ten years (60 percent). These probabilities have then been used to calculate the intermediate probabilties presented in Table 11. Annual benefits for each scenario have also been assumed, based on the potential annual benefits shown earlier in Table 9. These represent the benefits expected to accrue once biological control has been established at the full impact level of each scenario.

Combining the probabilities with the annual benefits presented in Table 11, the expected benefit in a given year can be calculated by multiplying the probability by the benefit. Table 12 illustrates this. It is assumed that agents are first released in year five of the biocontrol programme. It is also assumed that the level of annual benefit achieved rises exponentially to the full impact level over the lead time period of zero, five or ten years. Once agents are established under all scenarios, the expected annual benefit is $205,000.

Table 12

Calculation of Expected Benefits

Scenario	Lead Time	Probability	Benefit in Year 0 (Project Commenced)	5 (First Releases)	6	7	8	9	10	15 (Full Impact Established)
Nil	-	0.5	0	0	0	0	0	0	0	0
Low	0	0.0125	0	20000	20000	20000	20000	20000	20000	20000
Low	5	0.0875	0	366	996	2707	7358	20000	20000	20000
Low	10	0.15	0	2	7	18	50	135	366	20000
Medium	0	0.01	0	500000	500000	500000	500000	500000	500000	500000
Medium	5	0.07	0	9158	24894	67668	183940	500000	500000	500000
Medium	10	0.12	0	62	168	456	1239	3369	9158	500000
High	0	0.0025	0	2 Million	2 Million	2 Million	2 Million	2 Million	2 Million	2 Million
High	5	0.0175	0	36631	99574	270671	735759	2 Million	2 Million	2 Million
High	10	0.03	0	246	670	1822	4956	13474	36630	2 Million
Expected Benefit ($)			0	11579	13863	20072	36950	82950	84253	205000

Notes: 1. The expected benefits shown have been rounded

2. The expected benefit in each year is determined by summing the products of the probabilities and benefits for each possible outcome e.g. Expected Benefit in Year 5 = (0.5 x $0) + (0.0125 x $20,000) + (0.0875 x $366) + (0.15 x $2) + (0.01 x $500,000) + (0.07 x $9,158) + (0.12 x $62) + (0.0025 x $2 million) + (0.0175 x $36,631) + (0.03 x $246) = $11,579.

The costs of undertaking the biocontrol project must also be estimated. The estimated costs of a project to introduce two agents were presented earlier in Table 8. For the current analysis these costs are used. Table 13 shows how the costs can be subtracted from the expected benefits to give a net benefit in any year. Because of the long term time frame involved it is necessary to discount these net benefits to account for a positive time preference. In this study a discount rate of 10% is used. Table 13 also presents the discounted present values of the net benefits. It can be seen that the accumulated net present values of benefits does not become positive until year 19, so that it takes 14 years from release of the agents for the project costs to be recovered, under the assumptions used.

The table could of course be extended beyond 30 years. The annual net benefit of $205,000 would continue forever, under the assumptions used. In that case the cumulative value of the present values to infinity is $360,000, which represents an internal rate of return for the project of 14.7%. The internal rate of return criterion represents a useful benchmark for comparing similar projects or the same project under a range of different assumptions.

The decision theory approach illustrated above is easily implemented using spreadsheet software on a microcomputer. It therefore offers a flexible tool for performing sensitivity analysis on the assumptions made, particularly those regarding probabilities and benefits. Questions regarding resource allocation could also be examined. For instance, one interesting issue to examine is the impact of increasing expenditure at the rearing stage of a project in order to reduce the probable lead time for agents to achieve full impact. Additional benefits can be incorporated within the same framework. No attempt has been made to quantify the non-market benefits biocontrol of hieracium may have in conservation areas, yet some consider these to be as important as the benefits to agriculture identified. The benefits used in the analysis can easily be changed to account for differing assumptions or simply to perform some sensitivity analysis.

The analysis has been based on the estimates calculated for the current costs of hieracium and no allowance has been made for the possible future spread of the weeds. If it is believed that hieràcium species are in fact likely to spread in future, and that biocontrol could restrict that spread, the benefits to be used in the analysis could actually rise over time. This possibilty could also be explored using the decision theory framework presented.

Table 13
Present Value Calculations (Using a Discount Rate of 10%)

Year	Biocontrol Programme Costs (1)	Expected Benefits (2)	Net Expected Benefits (2)-(1)	Present Value of Net Expected Benefits in Year 0	Cumulative Net Present Value
1	40000	0	- 40000	- 36364	- 36364
2	40000	0	- 40000	- 33058	- 69421
3	90000	0	- 90000	- 67618	-137039
4	200000	0	-200000	-136602	-273642
5	140000	11579	-128420	- 79739	-353381
6	140000	13863	-126136	- 71201	-425582
7	0	20072	20072	10300	-414282
8	0	36950	36950	17238	-397044
9	0	82828	82828	35127	-361917
10	0	84253	84253	32483	-329433
11	0	88124	88124	30887	-298547
12	0	98646	98646	31432	-267115
13	0	127249	127249	36860	-230255
14	0	205000	205000	53983	-176272
15	0	205000	205000	49075	-127197
16	0	205000	205000	44614	- 82584
17	0	205000	205000	40558	- 42025
18	0	205000	205000	36871	- 5154
19	0	205000	205000	33519	28365
20	0	205000	205000	30472	58837
21	0	205000	205000	27702	86539
22	0	205000	205000	25183	111722
23	0	205000	205000	22894	134616
24	0	205000	205000	20813	155429
25	0	205000	205000	18921	174349
26	0	205000	205000	17201	191550
27	0	205000	205000	15637	207187
28	0	205000	205000	14215	221402
29	0	205000	205000	12923	234325
30	0	205000	205000	11748	246074

CHAPTER 6

CONCLUSIONS

Hieracium species are clearly of economic concern particularly to farmers in South Island high country areas. Estimates of the value of production lost due to these weeds, discussed in Chapter 3, ranged up to $4.4 million annually in the moderate rainfall high country areas alone. If the weeds are still spreading, as many believe, even greater costs may be incurred in future. In many situations there is no practical method of removing or controlling hieracium so biological control represents an attractive possibility. The potential benefits of biocontrol may range up to $2 million or $3 million per annum, under the scenarios discussed in Chapter 5, and the only significant cost involved in establishing biological control agents is that incurred by the DSIR in introduction, establishment and related costs.

However, there are many uncertainties involved in biological control. There is a significant probability of failure, or of only a limited success being achieved. The preceding analysis suggests that under the assumptions used a biocontrol programme for hieracium could recover its costs within about 14 years of the release of agents, and would give an internal rate of return of 14.7%. The decision analysis approach presented in the previous Chapter gives a flexible framework within which to test a variety of different assumptions.

In conducting the analysis it has been necessary to make a large number of assumptions. These are believed to have been reasonable and conservative on the basis of the available information. Some sensitivity information is provided but readers who wish may test the effect of alternative assumptions for themselves.

No measurement of indirect costs and benefits was attempted. Some potential second round and elasticity effects were identified but not quantified. There are also a range of non-market values associated with biological control and with hieracium species themselves. The study has not explored the possibility that biological control may not be equally effective for all the hieracium species or the income distribution effects of successful biological control. Neither has it explored the potential spread of hieracium and what additional costs that may impose on the nation's farmers. Anecdotal evidence suggests that hieracium is already a greater problem than suggested by the surveys reported so the benefits discussed may understate the current situation.

Ultimately, any decision regarding biological control of any pest must also take into account a number of political factors which it is beyond the scope of this study to explore. However, the analysis presented should assist those involved in making a final decision regarding biological control of hieracium as it quantifies some of the costs of the weeds and provides a framework for further exploring the benefits of biocontrol.

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APPENDIX A

VALUE OF HIGH COUNTRY PRODUCTION, 1986/87

This Appendix details the data and assumptions used in calculating the value of high country production, by region. The two main sources of high country production data used were the annual survey of sheep and beef farms produced by the NZMWBES for 1986/87, and the 1986/87 high country production survey conducted by TGMLI and reported by Kerr and Abrahamson (1988). Additional, unpublished, data was obtained from both sources. The value of this production was estimated based on the 1988 medium term product price assumptions published by MAF (MAF Corp 1988) or, where these gave insufficient information, from MAF's situation and outlook figures (MAF Corp 1989). The following explanatory notes and tables briefly describe the steps taken to arrive at the final estimated value of $84 million for South Island high country production. This is the value to the nation in 1988 dollars of production at 1986-87 levels.

A.1 Regional Data

Table 14
High Country Farm Data, 1986/87 by Region

Region:	MM	CM	CW	OD	OM	OW	SM	Total
No. of farms(1982)	23	51	36	46	91	36	17	300
No. of farms in sample (1986/87)	8	26	26	25	49	18	7	159
Sheep Nos. (%)	6	14	12	16	31	11	11	100
Cattle Nos. (%)	31	8	9	6	17	16	13	100
Deer Nos (%)	6	12	29	5	15	14	19	100
Wool Sales (%)	5	12	15	17	32	10	9	100

Source: 1986/87 high country production survey, TGMLI, from unpublished survey data

Table 14 shows regional data relating to high country farms, stock numbers and wool sales obtained from unpublished results of the latest TGMLI high country production survey. No information about goats was available from this source, however. For the purposes of this study it was assumed that goats were distributed regionally on the same pattern as sheep. The seven regions used are those identified by the TGMLI and based on province and climate:

MM	=	Marlborough Moist	OM	=	Otago Moist
CM	=	Canterbury Moist	OW	=	Otago Wet
CW	=	Canterbury Wet	SM	=	Southland Moist
OD	=	Otago Dry			

A.2 Farm Production

A.1.2 Wool Production

Average wool production per high country farm in 1986/87 was 37201 kg, according to NZMWBES figures. This figure includes slipe wool production and adjustments for wool on sheeps back at the open and close of the year, and on stock traded during the year. Compared to this, Kerr and Abrahamson (1988) estimated production to be 35,725 kg per farm. The NZMWBES estimate is a more inclusive figure for total wool production.

However, in order to value shorn wool production for the purposes of this study, slipe wool must be subtracted from the wool production total. An allowance for a pelt payment is included in both the prime lamb and prime mutton price used. Assuming a 1 kg wool pull for both lambs and ewes, slipe wool production per farm is approximately 1,163 kg (1,083 export lamb sales, 100 prime ewe sales) according to NZMWBES estimates (R.Davison pers comm). This gives total shorn wool production, excluding slipe wool, of about 36,000 kg per farm, which is the figure assumed in this study.

A.2.2 Meat Production

Table 11 shows meat production for the average South Island high country farm in 1986-87 based on NZMWBES estimates.

Table 15
Meat Production per High Country Farm, 1986-87

	Kilograms
Lamb	19,575
Mutton	21,784
Beef	18,435
Deer	593
Goat	95

Source: NZMWBES

A.3 Product Prices

Table 16 shows the product prices assumed in valuing the production, with a discussion of the derivation of these prices in the following sub-sections.

Table 16
Mean Product Prices ($1988/kg)

Fine Wool (f.o.b.)	4.70
Other Wool (f.o.b.)	4.10
Slipe Wool	8.30
Prime Lamb (f.o.b.)	3.38
Other Lamb (ex-freezer)	1.72
Weighted Lamb Price	2.80
Prime Mutton (f.o.b.)	1.78
Other Mutton (ex-freezer)	0.68
Weighted Mutton Price	0.76
M. Cow (ex-works)	2.08
P1. Steer (ex-works)	2.41
Venison (f.o.b.)	9.35
Goat Meat (f.o.b.)	2.00

Note: Refer to discussion for fuller details of price derivation

Sources: MAFCorp Product Price Assumptions 1988
MAFCorp Situation and Outlook for New Zealand Agriculture 1989

With the exception of venison and goat meat, the prices used are taken from the MAFCorp Economic Consultancy Unit Publication "Product Price Assumptions 1988" (MAF 1988). These are medium term price projections intended for policy purposes and as such are more appropriate for this study than prices applying in any particular year. Brief details regarding each of the prices used are given below.

A.3.1 Wool

MAF (1988) gives the following mean prices for greasy and slipe and pelt wool:

	$ Per Kg
Mean price at f.o.b.	= 4.10
Mean price at auction	= 3.98
Slipe wool	= 8.30 (for both lamb and sheep skins)

It is stated that "for Merino and Corriedale wool, a fine wool premium of 15 percent at auction can be added to the mean, with the added values remaining the same." This gives rise to the $4.70 per kg price estimate for fine wools. It could be argued that current premiums, particularly for superfine wools, are higher than this but as has been emphasised already, the product price assumptions published by MAF reflect medium term projections based on a number of assumptions regarding future market conditions and are superior estimates for the purposes of the current analysis than current price levels. Using data from the high country production survey, Table 17 gives a breakdown of the estimated proportion of the wool clip in each region classed as fine, assuming this is equivalent to the proportion of fine wool bearing sheep breeds in that region. Merino, corriedale and merino half bred sheep were assumed to produce fine wool.

Table 17
Proportion of Fine Wool Production, 1986-87, by Region

	MM	CM	CW	OD	OM	OW	SM
% Fine Wool	85	90	90	85	75	80	75

Source: TGMLI high country production survey, 1986/87

Since a payment for slipe and pelts is included in the f.o.b. price used for prime lambs and ewes, the total value of slipe wool is derived from the numbers of prime stock sold per farm (See Table 18 in the following section), assuming a 1 kg wool pull.

A.3.2 Lamb and Mutton Prices

Table 18
Derivation of Lamb and Mutton Prices

	Lamb	Cull Ewe
Mean price f.o.b. ($/hd)	45	34.7
Mean c/c Weight (kg)	13.3	19.5
Mean f.o.b. price ($/kg)	3.38	1.78
All grades average mean ex-freezer ($/kg)	1.72	0.68
Prime stock sold per farm (head)	1083	100
Total stock sold per farm	1674	1456
Prime stock (%)	65	7

Source: MAF (1988), NZMWBES

As Table 18 shows, mean prices for lamb and mutton, both f.o.b. and ex-freezer, were obtained directly from MAF (1988) and expressed in dollars per kilogram. If these prices are weighted according to data on sales of prime stock on South Island high country farms, 1986-87, obtained from the NZMWBES survey, mean lamb and mutton prices can be derived:

Lamb Price = \$3.38 x 0.65 + \$1.72 x 0.35 = \$2.80/kg

Mutton Price = \$1.78 x 0.07 + \$0.68 x 0.93 = \$0.76/kg

It should be noted that these prices include an allowance for a wool and pelt payment for prime stock. This is presented separately in Table 20, based on the assumptions regarding slipe production given in Section A.2.1).

A.3.3 Beef Prices

The M cow all grades average price of \$2.08 per kg was used for beef in this study, assuming high country beef production to be predominantly this grade.

A.3.4 Deer and Goat Prices

MAF (1988) gave the following deer and goat product values:

	Mean Price
Velvet \$ per kg at farm gate	83.7
Venison \$ per kg carcass weight at deer slaughtering premises	5.5
Cashmere \$ per kg down (at auction)	94.00
Cashgora \$ per kg fleece (at auction)	23.00

In order to derive f.o.b. prices for venison and goat meat MAF (1989) projections on the f.o.b. value, and volume, of exports was used.

Table 19
Venison and Goat Meat F.O.B. Values

	1989/90 Export Volume Forecast (Tonnes)	1989/90 f.o.b. Export Value (Forecast $1000)	Derived $/Kg (f.o.b.)
Venison	4600	43000	9.35
Goat Meat	900	1800	2.00

Source: MAF (1989)

A.4 Value of Production by Region

The above prices together with 1986-87 production levels for wool and meat products, were used to derive the total value of high country production (in 1988 dollars). In order to break this down to a regional level, the weightings shown earlier in Table 14 were used in the following manner:

Shorn wool production weighted by wool sales
Slipe wool, lamb and mutton production weighted by sheep numbers
Beef production weighted by cattle numbers
Venison production weighted by deer numbers
Goat production weighted by sheep numbers.

As insufficient data was available on velvet, goat fibre and crop production, these additional sources of production were omitted. Table 20 shows the estimated value of high country production, by region and Table 21 shows the percentage of total value derived from each source. Also given in Table 21 is the percentage of gross income from each of wool, sheep, cattle and other for high country farms in the 1986/87 NZMWBES survey, for comparison purposes.

Table 20
Estimated Value of High Country Production, by Region
(1988 dollars)

	MM	CM	CW	OD	OM	OW	SM	Total
Shorn Wool	2489400	6013440	7516800	8463960	15724800	4946400	4422600	49577400
Slipe Wool	176740	412394	353480	471307	913158	324024	324024	2945670
Lamb	824427	1923664	1648854	2198473	4122137	1511450	1511450	13740457
Mutton	281889	657740	563778	751703	14094443	516796	516796	4698146
Beef	3566066	920275	1035309	690206	1955584	1840550	1495447	11503440
Venison	99802	199604	482376	83168	249505	232871	316039	1663365
Goat Meat	3420	7980	6840	9120	17100	6270	6270	57000
Total	7441744	10135097	11607438	12667938	24362271	9378361	8592626	84185478

Table 21
Percentage of Value From Each Source, by Region

	MM	CM	CW	OD	OM	OW	SM	Total	Average NZMWBES* High Country Farm 1986/87
Wool	36	64	68	71	68	56	55	62.4	62.8
Sheep	15	25	19	23	23	22	24	21.9	18.2
Cattle	48	9	9	5	8	20	17	13.9	15.4
Other	1	2	4	1	1	2	4	2.0	3.6
Total	100	100	100	100	100	100	100	100.0	100.0

* Proportion of gross income from each source (NZMWBES 1988)

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