THE ECONOMICS OF CONTROLLING GORSE IN HILL COUNTRY:
GOATS VERSUS CHEMICALS

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PREFACE

This report examines the economics of controlling gorse either by chemical or by biological means utilising the goat animal. The benefits from gorse control by either means are usually considered to lie in the area of increased sheep carrying capacity and/or performance. But, as the report identifies, some goat grazing enterprises may have significant economic potential in themselves.

The study is also timely given the recent removal of the Government's subsidy on weedicides and the increasing public awareness of the dangers of chemical uses.

The report was compiled by Mr M.A. Krause (on leave from the South Australian Department of Agriculture), Mr A.C. Beck (Senior Research Economist in the A.E.R.U.), and Professor J.B. Dent (Professor of Farm Management in the Department of Farm Management and Rural Valuation at the College). Financial assistance provided by the Department of Scientific and Industrial Research is gratefully acknowledged.

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Director
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Information and data essential for this study were made readily available from research trials at Ballantrae and Loburn. For this the assistance and co-operation of Dr Phil Rolston (D.S.I.R.), Mr Dave Clark (D.S.I.R.), Mr Greg Lambert (D.S.I.R.) and Dr Joan Radcliffe (M.A.F.) is gratefully acknowledged. Additional assistance provided by Mr Ross Moorhouse (M.A.F.) and Mr Keith Thompson (Lincoln College) was also appreciated. This appreciation is extended to the people listed in personal communication for their co-operation.

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SUMMARY

The aim of this study was to assess the economics of controlling gorse in hill country by comparing the use of goat and sheep grazing with chemical control. The New Zealand environment has suited the growth of gorse (an introduced species) to such an extent that this plant has become a major weed problem throughout New Zealand. Traditionally, gorse has been controlled by spray programs, but this method is costly and has met with limited success. Recent research has shown the grazing of goats and sheep to be a possible alternative for gorse control.

A simulation model was constructed which includes the physical and economic aspects of a hill country grazing system. Extensive sensitivity analysis and experimentation were carried out using the model to evaluate alternative control strategies under different price and production scenarios. In particular, the following goat production options were considered for gorse control (in conjunction with sheep production):

- feral does with income from progeny sold for meat;
- feral goats with income from cashmere;
- first and second cross wether goats with income from "cashgora";
- feral does crossed to angora bucks with doe kids sold as first cross and wether kids sold for scrub control.

These control options were assessed under a range of goat grazing rates, and were compared with the traditional burn and spray method of gorse control. All goat and sheep control options proved to be more profitable than the chemical method, with the "feral does x angora bucks" option proving particularly profitable. These results proved robust for a wide range of sheep, goats and chemical price scenarios and there would seem little doubt as to the economic superiority of using goat/sheep strategies for gorse control.

The study concludes with a discussion of the results given both short- and long-term market expectations, including some consideration of future research priorities in this field.

Keywords: gorse control; chemical; goats; sheep; economic analysis; simulation; deterministic model; sensitivity analysis; complementary grazing.
1.1 General Background

Gorse (Ulex europaeus) is the most feared scrub weed in New Zealand grazing land (Bell, 1961; Moffatt, 1965). This weed has infected 657,000 hectares of New Zealand's pastures (Blaschke et al., 1981) and past attempts at eradication of gorse from hill country have met with limited success (Clark et al., 1982). A study conducted by Kaplan in the Mangamahu Valley (North Island) indicated that 94 per cent of the farmers surveyed listed scrub and gorse control as being the major problem of their under-developed land (Molloy, 1980). This is reflected in the government chemical subsidy for noxious plant control, 61.6 per cent of which was required for gorse control in the six years prior to 1982 (Ministry of Agriculture and Fisheries (M.A.F.)).

The traditional method of gorse control in hill country is to blanket spray mature gorse with 2,4,5-T, then after a few months burn the gorse stand. Regrowth is controlled by follow-up spraying and/or the mob stocking of sheep. This method has proven costly (Ritchie, 1982) and time-consuming and has given variable results. The economics of spraying have also been affected recently by the removal of the government chemical subsidy for noxious plant control.

Recent trial work with goats has shown that they have the potential to reclaim and control gorse infected pastures (Rolston et al., 1981a; Radcliffe, 1982). Gorse control by the use of correct goat management may well be a viable and effective alternative to the traditional method. The prospects seem particularly good for hill country where the use of goat and sheep grazing to reclaim gorse infected country could provide the economic alternative needed to regain the full potential of hill country grazing.

1.2 The Problem

1.2.1 Nature of the problem.

Gorse was initially introduced into New Zealand for hedges and as a shelter for livestock. The plant adapted so well to New Zealand conditions that it has spread and become a major problem in pastures. While it does not compete with pasture in its early growing phase (Iven, 1978), once established it soon over-takes pasture and greatly decreases
the grazing potential for sheep and cattle. Its control is made difficult since gorse seed can remain dormant in the ground for up to 30 years (Matthews, 1975). This means a control program must be maintained for a long period.

The use of chemicals, especially 2,4,5-T can be effective in the eradication of gorse bushes (Moffatt, 1965); however, follow-up spot spraying for continued control of regrowth and seedlings requires good management. High labour input is required for spot spraying and with high labour costs, this part of the spray control program has tended to be neglected. When this occurs, the pasture becomes re-infested with gorse within a few years.

Prior to the 1982 budget, government subsidies were available for gorse spray eradication programs as part of the Noxious Plants Control Scheme. These subsidies have now been removed and with the escalating price of chemicals, the spray method of controlling gorse has become quite expensive. The initial blanket spray is usually applied by air in hill country (Meeklah, 1981), which has also added to the cost of using chemicals. This method has proven to be expensive and time-consuming and this has encouraged research on alternative methods of gorse control.

The use of blanket spraying with chemicals has also caused problems with clover establishment (Maclean, 1957). A hidden cost in using chemicals is the slow pasture establishment after spraying, causing a decrease in animal production.

Mob stocking with sheep has also been used, but this method has met with limited success. Sheep have demonstrated a preference for clovers and grasses to gorse (Lambert et al, 1981; Radcliffe, 1982). Sheep will only graze gorse if heavily stocked (200 sheep per hectare) and for gorse to be controlled, good management is required. Gorse has a similar growth pattern to pasture and requires most grazing control during the spring flush (Rolston et al, 1981a). A farmer must either graze ewes with lambs and wean lambs early, or purchase wethers specifically to control gorse. If ewes are grazed on gorse, their potential production will be affected by being forced to graze poorer pasture. This approach requires good management and tends to decrease the economic potential of the sheep involved.

Goats have been used to control gorse with a high degree of success (Rolston et al, 1981a; Radcliffe, 1982), and have been shown to browse gorse preferentially before pasture (Clark et al, 1982). This method shows potential not only in the control of gorse but also the increased animal production off gorse infected pastures during the control period. Since goats prefer gorse to pasture and sheep prefer pasture to gorse, in the initial stages of gorse control there is a high degree of complementary grazing between the two (Lambert et al, 1981).

2. Spot spraying implies the individual spraying of gorse plants by a hand held device.
Therefore a possible economic strategy to control gorse could be to initially graze heavily with goats, and as the gorse offers less competition to pastures, gradually replace the goats with sheep.

Long-term control of gorse is also possible using this method. Since goats preferentially graze gorse, any regrowth or germination could be controlled by a light grazing pressure of goats, which means that a high level of management and costs would not be required.

Goat grazing may also be preferred because it provides a purely biological means of controlling gorse. Therefore, this method is more environmentally acceptable than the use of chemicals (Vere, 1979) about which there has been recent public controversy (Molloy, 1980).

Gorse is a major problem to New Zealand grazing and a number of methods have been used to control gorse. These methods have given varied success and with increasing costs, new alternative methods must be sought. Goats appear to offer both long term and cheap gorse control, but further information is needed on their economic advantages.

1.2.2 The need for research.

The problem of gorse infestation decreasing the productive potential of hill country is a major concern to agriculture in New Zealand. An economic assessment of this problem has shown the potential of using goats for gorse control (Ritchie, 1982); however, this analysis did not allow for the dynamic nature of the goat/gorse control system or complementary grazing in reclaiming gorse. By simulating this system and determining the sensitivities of physical and economic parameters, greater insight can be gained into the economics of using goats to control gorse within the hill country farming system. No study of this type has been carried out on this problem, thus this study should improve understanding and give greater insight into factors affecting the economics of reclaiming gorse infested pasture.

It was decided to concentrate specifically on the hill country of the North Island of New Zealand for three reasons. Firstly, there is a major problem of gorse infestation in the hill country (Molloy, 1980) and a comprehensive study of the problem would directly benefit this area.

Secondly, research work on goats and sheep controlling gorse at Ballantrae Research Station (Department of Science and Industrial Research (D.S.I.R.)) near Woodville has produced relevant results. Consequently, this research provides the basic information for model construction and validation. The results are therefore relevant specifically to North Island hill country.

Thirdly, a study of one particular region could identify certain characteristics specific to that region. Results from goat and sheep grazing trials on gorse infested land at Loburn (North Canterbury) (M.A.F.) are available, but if these were to be directly included in this study, certain regionally specific effects could be ignored. The
4.

Loburn results are therefore referred to only as an indirect guide in developing the model.

1.3 **Aim of the Study**

The objective of this study was to assess the economic costs and benefits of reclaiming gorse infested hill country using both sheep and goats within an intensive grazing situation. In analysing this system, the sensitivities to different market situations, economic variations, and farm management strategies were investigated. Thus the final outcome is an appreciation of the range of strategies available to farmers and an indication of which is likely to be the optimal strategy. The goat/sheep strategies were evaluated against the benchmark of current gorse control strategies involving burning and herbicides.
2.1 Introduction

The previous chapter described the nature of the gorse problem in New Zealand. Various features of the gorse control system of hill country are discussed in this chapter.

The majority of data assessed to determine the biological aspects of the grazing control of gorse came from the Ballantrae trial. Additional information from the Loburn trial was used where necessary. Both trials were set up to assess different grazing combinations of goats and sheep and their effects on gorse in hill country. The grazing combinations at the Ballantrae trial were: all goats and no sheep; 66 per cent goats and 33 per cent sheep; 33 per cent goats and 66 per cent sheep; all sheep and no goats; and sheep mob grazing (Rolston et al, 1981b). At the commencement of this trial stocking rates for each treatment were: 18 goats per hectare and no sheep; 12 goats and 3 sheep per hectare; 6 goats and 6 sheep per hectare; no goats and 9 sheep per hectare; and 250 sheep per hectare for mob stocking. At these stocking rates a sheep was 1.0 S.U. and a goat 0.5 S.U.

The Loburn trial involved treatments of: all goats and no sheep; 50 per cent of both sheep and goats; all goats and no sheep; and mob stocking of sheep (Radcliffe, 1982). At the beginning of this trial the stocking rate of the treatments were: 20 goats per hectare; 10 goats and 5 sheep per hectare; 10 sheep per hectare; and 200 sheep per hectare for mob stocking. As at Ballantrae, in this trial, to determine stocking pressure, 2 goats were equated to 1 sheep. Even though a reassessment of stocking rates was made during both trials, the proportions of sheep to goats were maintained (Rolston et al, 1981a; Radcliffe, 1982).

2.2 Animal Characteristics

2.2.1 Goats.

The ability of goats to control, utilize and reclaim weed infested country has been known for many years (Wright, 1927; Devendra, 1978). Their diet selection habits make these animals well-suited to the biological control of gorse.
(1) Diet selection by goats.

Goats prefer browse as a dietary selection and will, if forage on offer allows, select over 50 per cent of their diet on browse (Clark et al, 1982; Devendra, 1978).

Trials conducted at Ballantrae Research Station indicated goats preferred gorse and thistle to grass and clovers (Clark et al, 1982). Where gorse was greater than 10 per cent of the associated pasture, it was the principal feed for goats and where gorse on offer allowed, it made up to 95 per cent of goat's dietary selection. These results illustrate goats' direct preference for gorse and their potential for suppressing of gorse growth in New Zealand pastures.

The next preferred diet selection was grass and this was only preferred if gorse and thistle were not adequately on offer (Clark et al, 1982). Intake of clover by goats was minimal, resulting in clover dominant pastures. As the ratio of goats to sheep increased, the white clover within the pasture increased and the proportion of gorse decreased.

The specific reasons for the goat's diet preferences are not clear, but Devendra (1978) suggests that goats have a higher digestive efficiency of cellulose than either cattle or sheep. Goats can therefore digest roughage more efficiently. It is not certain whether goats thrive better on browse than pasture (Kirton and Ritchie, 1979), but they do show a specific preference for browse. Another reason goats are more suited to browse than other ruminants is their mobile upper lip (Devendra, 1978; Batten, 1979a); forage that cannot be obtained by sheep or cattle may be accessible to goats.

Since goats actively select gorse, they provide not only a short term strategy for reclaiming gorse infested country, but also a long term control where gorse regrowth or seedlings are a problem.

(2) Rate of gorse control by goats.

Batten (1979b) suggested that the higher the goat grazing intensity, the quicker the control of gorse infested country. This relationship is evident in both the Ballantrae (Rolston et al, 1981a) and Loburn (Radcliffe, 1982) trials. Height measurements of gorse were taken on the Ballantrae trial with the results under different goat grazing pressures shown in Figure 2. Figure 2 illustrates the measured growth of gorse at Ballantrae and together with Figure 2 gives an insight into the goat controlling gorse system. If the measurement of gorse height can be taken as a direct indication of gorse control, then the higher the goat grazing ratio, the greater the control of gorse. The 'no goat' grazing situation had 9 ewes per hectare, and showed little control over the gorse. Gorse control also varied between seasons with the greater control occurring during autumn and winter. The greatest control is needed during the spring and summer flush to prevent the re-establishment of gorse. Goat grazing pressures of 12 and 18 goats per hectare showed the best control during these seasons.
FIGURE 1: GORSE GROWTH RATE RECORDED AT THE BALLANTRAIE TRIAL (Rolston et. al., 1981a)

FIGURE 2: AVERAGE GORSE HEIGHT UNDER DIFFERENT GOAT STOCKING RATES AT THE BALLANTRAIE TRIAL (Rolston et. al., 1981a)
A similar relationship was shown in results from Loburn (Radcliffe, 1982). The marginal rate of gorse control to goat stocking rates is shown in Figure 3. These figures were derived from an annual percentage change in gorse height. While both trials had different initial levels of gorse density and different trial commencement dates, they both indicated declining gorse height with increased goat grazing intensities. The two results do differ in the type of goat to gorse-control relationship. A declining linear relationship is indicated by the Loburn figures, while decreasing marginal control of gorse is shown by the results from Ballantrae. The difference is most likely due to the different gorse densities between the two trial sites with the Loburn trial having the higher density; however, both trial results illustrate a definite increase in the rate of gorse control with increasing goat grazing pressure.

(3) Types of goat used in gorse control.

The three major types of goats found in New Zealand are Angora, milk goats and feral. All types of goats have the potential to control gorse weeds. McKinnon (1982) reports of Angoras used to control Sweet Briar, and Leighton (1978) cites milking goats used in the control of gorse. Feral goats have been used in the Ballantrae and Loburn trials.

Feral goats appear to be the only practical type of goat available to many New Zealand farmers for the control of gorse. Angora and milking goats provide a higher profit potential than ferals (Ritchie, 1981a; Ritchie, 1981b; Ritchie, 1982) but to realize their optimal economic return they require reasonably high producing pastures (Batten, 1982). Angoras are also likely to be unsuitable for intensive weed control due to problems with their long coats getting entangled in dense scrub and gorse (Batten, 1979b). Thus, using angoras for gorse eradication could decrease their potential monetary return. New Zealand's population of Angoras and milking goats is quite small (Kirton and Ritchie, 1979) and most herds are still in the building-up stages. This has meant that there is a shortage of animals available for sale and these goat types command a high price. Feral goats on the other hand are more readily available and are the common choice where large numbers of goats are required for gorse control. For these reasons only the use of feral goats were assessed in this study.

Farmers may consider upgrading their feral flocks to have more Angora or milk characteristics. This may, in the long term, provide a profitable goat enterprise. However, since the objective of this study was to assess the economics of goats for gorse control, and not as a continuing enterprise, this management option was not evaluated.

2.2.2 Sheep.

Sheep have traditionally been used within gorse control strategies with varying success. Being readily available within the farm is the main advantage in using sheep. Also, they potentially yield a greater financial return than the common feral goat enterprises; however, good
FIGURE 3: FIRST YEAR CHANGE IN GORSE HEIGHT TO GOAT STOCKING RATES IN THE BALLANTRAЕ AND LOBURN TRIALS
management is required if sheep are to control gorse, since sheep will not actively select gorse.

(1) **Diet selection by sheep.**

Clark et al (1982) found sheep had dietary selections that differed substantially from goats. Sheep preferred clover and grass to gorse and will consume clover to the proportion on offer in the pasture. Grasses were found to be the major component in sheep diet in all seasons and the gorse contribution was negligible. In the trial at Ballantrae, the higher the proportion of sheep grazing a plot, the lower was the clover content and the higher the gorse content in the pasture. Therefore, if sheep are allowed to graze at normal stocking rates (9 S.U. per hectare), little or no pressure is applied to the gorse. At this stocking rate sheep will eat gorse if only gorse is available, but will not apply enough pressure to eradicate the plant. Normally, sheep only show signs of controlling gorse growth under intensive mob stocking grazing management (Rolston et al, 1981a; Radcliffe, 1982).

(2) **Rate of gorse control by sheep.**

Since sheep do not actively select gorse, the control of gorse by sheep would only occur under high grazing pressure. This was found to be the case in both the Ballantrae (Rolston et al, 1981a) and Loburn (Radcliffe, 1982) trials. Using height as an indication of gorse control, Figure 4 illustrates the effect of both mob stocking and normal stocking of sheep in the Ballantrae trial. The gorse was initially burnt before the trial was grazed and over the first year a stocking rate of 9 ewes per hectare showed little control over the gorse. Mob stocking on the other hand did have some effect on gorse height, demonstrating similar control rates to the 6 goats per hectare stocking rate as seen in Figure 2. These results were also evident in the Loburn trial (Radcliffe, 1982).

Mob stocking also offers physical control over gorse seedlings by trampling effects. The higher the stocking rate, the greater the trampling and thus the number of seedlings killed. Mob stocking recorded the highest percentage kill of gorse seedlings in the Ballantrae trial (Rolston et al, 1981a).

(3) **Importance of clover for optimal sheep production.**

Clovers within pastures are important to achieve optimum sheep production. In an experiment at Invermay Research Station, Lewis (1957) concluded that there was a direct relationship between the quantity of clover in the pasture and the growth performance of fat lambs. The chemical 2,4-D was used to suppress clovers and these replicated plots resulted in significant decreases in fat lamb growth rates compared to the control plots. This decrease in fat lamb performance was evident where clovers were suppressed even though there was an abundance of available feed. Therefore, clovers improve the nutritional value of
FIGURE 4: AVERAGE GORSE HEIGHT UNDER DIFFERENT SHEEP STOCKING RATES IN THE BALLANTRAЕ TRIAL
(Rolston et. al., 1981a)
pastures for sheep production and are necessary if optimal sheep production is to be achieved.

2.2.3 Complementary grazing between goats and sheep.

Since sheep have been shown to select clovers in preference to grasses, and goats to select gorse rather than grass (Clark et al, 1982), a degree of complementary grazing is possible. Economic advantages in complementary grazing have been demonstrated in Texas (U.S.) and Western Australia, and this is the method of livestock management common in nomadism and transhumance of the Near East region (Devendra, 1978). Squires (1982) has in fact found that there is a higher degree of dietary overlap between goats and cattle than between the more complementary goats and sheep. Therefore, it would appear that even during gorse control with goats, higher animal production per area can be obtained than if sheep only were used in the gorse control strategy.

The degree of complementary and competitive grazing can be gauged from the trial results at Ballantrae. Clark et al (1982) describe the change in pasture composition and the degree of dietary overlap between goats and sheep. Further records from the trial relate the change in ewe live weights to the changing pasture composition and different sheep/goat stocking ratios, which reflects the complementarity in grazing.

(1) Pasture composition.

As the trial proceeded, change in pasture composition was evident. Figures 5, 6, 7 and 8 show the seasonal amounts of white clover and gorse on offer in the four grazing treatments. Two distinct trends are obvious. Firstly, as the stocking proportion of goats increases, so does the availability of white clover on offer. Conversely, as the proportion of sheep increases, the amount of white clover on offer decreases. This illustrates the direct effect both goats and sheep have on the availability of clover within the pasture.

Secondly, the degree of gorse on offer is affected by the grazing intensity of goats and/or sheep. Figures 5 and 6 show the minimal amount of gorse on offer under the two heaviest goat grazing intensities. As goat grazing intensity decreases, the proportion of gorse on offer increases (Figures 7 and 8). Likewise, as the proportion of sheep grazing increases so does the availability of gorse.

These results illustrate both the diverse dietary selection of goats and sheep, and their effect on pasture composition.

(2) Competitive grazing.

At Ballantrae, Clark et al (1982) estimated the degree of competitive grazing that would occur in each treatment situation (if grazed by equal numbers of sheep and goats) by calculating the
FIGURE 5: SEASONAL CONTRIBUTION OF WHITE CLOVER AND GORSE TO FORAGE ON OFFER AS ESTIMATED BY 'FIRST HIT' POINT ANALYSIS FOR 100% GOATS TREATMENT (Clark et al., 1982)

FIGURE 6: SEASONAL CONTRIBUTION OF WHITE CLOVER AND GORSE TO FORAGE ON OFFER AS ESTIMATED BY 'FIRST HIT' POINT ANALYSIS FOR 66% GOATS TREATMENT (Clark et al., 1982)
FIGURE 7: SEASONAL CONTRIBUTION OF WHITE CLOVER AND GORSE TO FORAGE ON OFFER AS ESTIMATED BY 'FIRST HIT' POINT ANALYSIS FOR 33% GOATS TREATMENT (Clark et. al., 1982)

FIGURE 8: SEASONAL CONTRIBUTION OF WHITE CLOVER AND GORSE TO FORAGE ON OFFER AS ESTIMATED BY 'FIRST HIT' POINT ANALYSIS FOR 0% GOAT TREATMENT (Clark et. al., 1982)
Kuluyznski’s similarity coefficient. This coefficient is estimated by sampling the intake by fistulated goats and sheep placed on the treatment sites. The coefficient is measured using the following formula:

\[
S = \frac{2w}{a + b}
\]

where: \( w \) = the sum of the lowest percentage of each pasture species type when comparing both sheep and goat percentage of diet intake

\( a \) = sum of the diet components (per cent) for sheep

\( b \) = sum of the diet components (per cent) for goats.

The value ‘\( S \)’ then is a measure of diet similarity, where the extremes are \( S = 1 \) indicating perfect diet similarity, and \( S = 0 \) showing complete dissimilarity in diet.

Figure 9 illustrates the seasonal similarity estimates ‘\( S \)’. The general result indicated that when grass was the major pasture species on offer, there was a high degree of diet similarity. This usually occurred during spring and is evident in both the 100 per cent goat and 66 per cent goat treatments. In the 100 per cent sheep and 33 per cent goats, a higher proportion of gorse was on offer resulting in a lesser degree of diet similarity. Dissimilarity in diet also occurred during late summer and autumn when clover growth was at a premium. Sheep would actively select the clover if it was available and thus there was a certain degree of dissimilarity in the 100 and 66 per cent goat treatments where clover was more readily available. A high degree of diet similarity occurred in the 66 per cent goats, because the goats had controlled the gorse and sheep had heavily grazed the clover, leaving only grass to be the common pasture species. Therefore, diet similarity only occurred when both the gorse and clover had been well controlled leaving grass to be the common diet.

(3) Ewe live weights.

The performance of ewe live weights in the Ballantrae trial also illustrated the benefits of complementary grazing with goats. In Figure 10 the recorded average ewe live weights are shown. It is difficult to ascertain any trend in the first year since initial ewe live weights did not commence at similar levels. If live weights can be used as a guide to ewe production, the treatment of 33 per cent sheep gave the best ewe production over the second year of the trial. This can be directly attributed to the higher proportion of clover on offer caused by the grazing combination of goats and sheep. The same ewe production was not evident in the 100 and 66 percent sheep treatments in the second year because clover production had been reduced by the heavier sheep grazing.
FIGURE 9: SEASONAL SIMILARITY COEFFICIENTS FOR GOAT AND SHEEP GRAZING TREATMENTS IN THE BALLANTRAЕ TRIAL (Clark et al., 1982)
FIGURE 10: LIVEWEIGHT OF EWES IN THE BALLANTRAE TRIAL

33% Sheep
12 goats/ha

66% Sheep
6 goats/ha

100% Sheep
0 goats/ha
2.3 Plant Characteristics

2.3.1 Gorse.

Gorse is a hardy legume that will grow on most soil types (Mecklah, 1981) but prefers high fertility soils. The height of this plant varies with soil fertility and can grow to heights of 5 metres (Matthews, 1975). Heavy stands of gorse effectively limit pasture production and thus prevent viable sheep grazing.

The growth pattern of gorse is similar to pasture, as seen in Figure 11, with the major growth period being spring and early summer. If gorse is to be controlled by grazing, spring and early summer is the period when heavy grazing is most essential.

Gorse will spread by seed quite rapidly (Matthews, 1975) with an estimated seed drop of 500-600 per square metre from a reasonable stand of gorse (Ivens, 1978). Gorse seeds are also capable of a dormancy period of up to 30 years and seeds have been counted as dense as 10000 per square metre (Ivens, 1978) which indicate the capacity of the plant for regeneration. Burning will destroy gorse foliage but fire stimulates germination. If plants are over 300mm high they have the capacity for root regrowth after burning (Matthews, 1975).

The main weakness in the life-cycle of gorse is in the early stages of growth when it does not compete well with pasture (Rolston, 1981a; Meeklah, 1981). Maintaining a good producing pasture should therefore limit the establishment of gorse; however, once gorse is established there is minimal competition from pasture.

Gorse also offers minimal competition to pasture if goats browse it heavily and contain the plants within their stump. At this stage, while the gorse is not dead, it effectively offers no barrier for the pasture to optimize sheep grazing potential (Clark and Rolston, 1983, pers. comm.3).

2.3.2 Pasture.

Good pasture management is essential for optimal animal production and the prevention of weeds. Pasture species will generally compete successfully with weed establishment given an average climate, adequate topdressing and good grazing management (Maclean, 1956). Good management includes using stocking rates and stock rotations that adequately utilize feed without overgrazing, thus preventing the establishment of weeds due to the lack of pasture competition. If weed encroachment is evident, then both pasture and grazing management must be reassessed carefully if optimal pasture production is to be regained.

3. A list of the people cited in personal communications is presented at the end of this Report.
With respect to gorse, if established gorse plants can be brought under control, and soil fertility is adequate, pasture will readily compete for the area previously under gorse (Rolston, 1983, pers. comm.). Thus, pasture production will increase proportionately as effective gorse cover is decreased.

The growth rate of pasture in hill country is shown in Figure 11. Most pasture production occurs during spring and summer with the peak in early summer. Optimal hill country pastures consist of grasses and clovers, both having different growth patterns. Grasses dominate pasture production during spring while the main production phase of clover is during summer and early autumn.

A limiting factor in production on hill country has been the lack of high producing perennial clovers (Suckling, 1975). Lewis (1957) found that the growth rate of lambs was reduced if clovers were suppressed in pasture. Even though the optimum proportion of clovers required in a pasture is not known accurately, it would appear that the encouragement of clover production in hill country is most important in pasture management.

2.3.3 Use of chemicals.

(1) Effect on gorse.

Of the herbicides used for gorse control, 2,4,5-T is the most efficient chemical on a cost-efficient basis (Matthews, 1975) and is used both for blanket spraying and spot spraying. To be successful, spraying must obtain complete foliage cover since unsprayed areas of the plant can resprout. Full coverage is dependent on the operator, spraying method and climatic conditions. Due to the difficulty in obtaining complete coverage and the regeneration potential of gorse, the spray program must continue for a number of years.

The effect of spraying on gorse is quite dramatic, however, for best results the gorse must be sprayed during certain growing periods. Seedlings are quite resistant to foliage spray applications and when gorse has reached the mature stage it is best burnt (Matthews, 1975). The ideal gorse growth phase for spraying is after the plant is established or when the plant is 0.6 to 1 metre high in a regrowth situation. Gorse regrowth is best sprayed between December and February, providing ample soil moisture is present (Matthews, 1975).

Chemicals are also used to improve the burning of mature gorse stands. Spraying four to six weeks prior to burning with the aim of desiccating the plants encourages a good burn (Matthews, 1975). Regrowth after burning can then be controlled by spot spraying.
FIGURE 11: COMPARISON OF PASTURE AND GORSE GROWTH PATTERNS AT THE BALLANTRAÉ TRIAL (Rolston, et al., 1981a)
21.

(2) **Effect on pasture.**

The effect of herbicides on clover production has been researched (Maclean, 1957; Hartley and Thomas, 1981; Bramley et al, 1967; Honore et al, 1980). These studies indicated decreases in pasture production by spraying with 2,4-D, MCP, MCPA, Picloram and 2,4,5-T. Unfortunately the majority of research has concentrated on chemicals other than 2,4,5-T, the chemical most used in gorse control; however, Matthews (1975) stated that 2,4,5-T has a detrimental effect on clover production and research reported by Maclean (1957) indicated that 2,4,5-T had a greater negative effect on dry matter (D.M.) production than 2,4-D. Rolston et al, (1981a) also report declines in clover D.M. production with the application of 2,4,5-T.

Clover suppression in pasture results in two major effects on pasture production:

(a) an immediate decrease in pasture production by the decrease in clover production,

(b) the decrease in nitrogen fixation affects the longer term production of grasses within the pasture.

The decline in clover production decreases livestock production, as shown by Hartley and Thomas (1981) in cattle and by Lewis (1957) in lambs. The regeneration of clover may also take up to a year after spraying (Bramley et al, 1967), which represents a decrease in economic return from livestock production. Since nitrogen fixation is also affected, grass production within the pasture may also decline. This may not occur immediately (Maclean, 1957) but grass production may suffer from nitrogen deficiencies.

The timing of herbicide spraying also affects the degree of clover suppression. Research with Picloram showed greater clover suppression if sprayed during a growth period (Bramley et al, 1967). Spraying during dormancy resulted in the least effect to clover production. Research conducted by J. Brock (reported by Rolston et al, 1981a) indicated a similar result using 2,4,5-T. A higher proportion of clover was suppressed with a spring spraying as opposed to a winter spraying.

The re-establishment of pasture after gorse control is necessary for both economic reasons and to maintain competition against gorse seedlings and regrowth. If chemicals are used, the establishment of clovers will be difficult in the short term, which effectively increases the length of time before reclaimed gorse country is returned to optimal production.

(3) **Timing of spraying with 2,4,5-T.**

If 2,4,5-T is to be used in gorse control, the timing of spraying will have a major effect on the gorse/pasture system. The optimal time for spraying gorse is between December and February (Matthews, 1975). This coincides with the growth period of clover, the most susceptible time for clover to be sprayed (Bramley et al, 1967). Hence there is a
22.

trade-off; the most effective period for the spraying of gorse is during the most susceptible time for clover suppression.

2.4 Insect Control of Gorse

There are some insects that can be used in gorse control, but none have been effectively demonstrated in New Zealand (Meeklah, 1981). A gorse seed weevil (Apicon ulicis) was introduced into New Zealand in 1931. This insect did establish itself successfully but the infestation of pods was variable in summer and non-existent in winter (Rolston et al, 1981a). Since this weevil only attacks seeds, it has no effect on the growth of gorse after germination and thus is irrelevant to this study (Hill, 1983, pers. comm.).

2.5 Climatic Effects

The effect of climate on gorse control systems is suspected to be minimal (Clark and Rolston, 1983, pers. comm.). The spraying of gorse is usually performed during favourable weather conditions by the operator. Apart from goats requiring shelter, their survival and production is not greatly affected by climate. Also, since climate is likely to affect the control of gorse under chemical or grazing strategies to a similar extent, it was not regarded as a major factor in this study.
CHAPTER 3

ECONOMIC AND MANAGEMENT FACTORS RELATED TO
THE CONTROL OF GORSE

3.1 Introduction

This chapter outlines the practical options available for the control of gorse with specific attention to managerial and economic aspects.

3.2 Management Options Available for Gorse Control

The area of gorse infestation to be redeveloped will differ between farms, along with the rate at which the areas will be redeveloped. All gorse infested land may be redeveloped at one time, or the area may be divided up and redeveloped in stages. Horgan’s (1979) blackberry clearing program concentrated on dividing the 121 hectares infested into 12 hectare blocks and redeveloping one block at a time. Whitehead (1980) reports a gorse clearing program in which a 30 hectare area was divided into 10 hectare paddocks which were also redeveloped sequentially. The preference is largely determined by the situation, the available finance and the speed at which the area is to be reclaimed. Since the objective of this study was to ascertain the economics of goats and sheep compared with chemicals in gorse control, a fixed area of 30 hectares was chosen. This area was selected as being typical and it was assumed that the effects of economies of size were not great for areas above 10 hectares. The assessment of the rate at which large areas of gorse infested hill country should be redeveloped was beyond the scope of this study, as it would affect both methods of gorse control equally. Therefore, all the 30 hectares were assumed to be redeveloped as one paddock.

The two major approaches available for gorse control on non-arable hill country are: the use of goats and sheep grazing combinations, or the use of chemicals. Variations within each approach are possible and some were included in this study to determine the most economic alternative.

3.2.1 Goats and sheep grazing combinations.

Both the grazing and chemical methods of gorse control involve an initial burn. Although gorse will burn freely, the intensity of burn is dependent upon the density of gorse, the climatic conditions and whether it has been sprayed prior to burning. The hotter the burn, the better the standing gorse is destroyed, and the quicker will be initial control.
24.

(Radcliffe and Rolston, 1983, pers. comm.). Spraying with 2,4,5-T three or four months prior to burning will result in an improved burn; however, to maintain a strict comparison between goat/sheep grazing and chemical control, the use of 2,4,5-T in this way was not included in the goat/sheep method.

Immediately after burning, re-sowing and topdressing is necessary for pasture establishment. This provides competition to gorse seedlings stimulated to growth by the fire.

The rate of stocking goats depends on the level of desired control. Once gorse has been decreased to the level where it offers negligible competition to pasture production, goat grazing intensity can be decreased to allow for the generally more profitable grazing of sheep. Since gorse seedlings will continue to germinate over a long period of time, a minimum stocking rate of goats will be required to help prevent reversion.

Feral goat enterprises have the potential of financial return from skins, meat and/or fibre during the gorse control program. Traditional returns can be gained from selling goat progeny for meat. The recent popularity of using goats for scrub and weed control, however, has meant that feral progeny can currently obtain higher prices being sold for scrub control rather than for meat. Current cashmere prices, coupled with the discovery that a proportion of feral goats in New Zealand can produce commercial quantities of cashmere, has meant there are potentially good returns from cashmere production. First and second cross angoras produce "cashgora" and at current cashgora prices also offer potential for a commercial return. Current mohair and angora prices have also opened another financial option for feral herds. The breeding of first cross angora does from ferals is proving a lucrative enterprise given current first cross angora prices. Therefore, fibre production and the sale of progeny are options available in goat enterprises for gorse control.

3.2.2 Chemical control.

Chemical control typically involves using a blanket spray of 2,4,5-T during October or November followed a few months later by burning the gorse. The area is then immediately topdressed by air with clover seed, rye grass seed and superphosphate. Follow-up light blanket spraying

4. Cashmere is the under down of a feral goat and is the finest fibre obtained from goats.

5. Cashgora is a fine fibre, the second finest goat fibre to cashmere. The processing and marketing is relatively new to the fabric industry.

6. Mohair is a fibre only obtained from Angora goats and is not as fine as cashmere and cashgora fibres.
with 2,4,5-T is then continued until gorse is completely eliminated from the pasture. Spot spraying should continue until complete eradication is achieved, which may take from 4 to 6 years (Mecklah, 1981) depending on the management of the redevelopment program and the effectiveness of the spraying. Mob stocking at 200-250 sheep per hectare is normally used throughout the redevelopment program primarily for the physical suppression of gorse seedlings. A detailed outline of this M.A.F. recommendation is given in Appendix 1.

3.3 Goat and Sheep Grazing Combinations

3.3.1 Management.

(1) Goats.

   (i) Herd Management.

   The management of feral goats can involve an autumn or spring kidding pattern (Batten, 1979c; Hogan, 1979;). Since goats are susceptible to exposure and most management orientation is for spring lambing, only the spring kidding management is considered. Management timing relating to spring kidding is shown in Figure 12. Does are mated between mid-February and mid-April, to kid from mid-July to October. This timing is similar to spring lambing since both sheep and goats have similar gestation periods (Sheppard and O’Donnell, 1979).

   To restrict kidding in the goat herd, the billy and young 8 month does must be kept separate from the main herd during certain times of the year (Batten, 1979c). This allows kidding to be confined to spring. Thus, a separate paddock for this purpose is required.

   To achieve an optimal kidding rate does should not be mated before 18 months of age or at less than 18 kg body weight (Batten, 1979c). This allows the does to develop adequately to produce kids with a higher survival rate and body weight gain. Kids are sold for slaughter at approximately 11 months of age. At this stage they should have reached 12 kg in body weight (Batten, 1979c). Horgan (1979) reported that at 9 to 12 months, wether kids reached 10 kg carcass weight and doe kids 8 kg carcass weight.

   Kidding percentages can be as high as 140 per cent; however, this only occurs where quality feed and shelter are readily available. Does used in scrub control do not obtain ideal feed quality and this is evident in lower kidding percentages. In Australia Vere and Holst (1979) assume a 75 per cent kidding rate for does used in blackberry control, while in New Zealand, Ritchie (1982) assumed 100 per cent kidding for does on gorse. The results from the Ballantrae trial indicated that a kidding rate of 80 per cent can be expected (Clark and Rolston, 1983, pers. comm.). In this analysis a kidding rate of 80 per cent was assumed.
FIGURE 12: MANAGEMENT STRATEGY FOR SPRING KIDDING
(Batten, 1979c)

- Slaughter stock muster
- Kidding starts
- Does kidding
- Kidding ends
- Unmated young
- Does and kids
- Marking muster
- Slaughter stock
- Muster all stock, bucks withdrawn
- Does and bucks
- Weaned young stock
- Weaning muster
- Dip all stock
- Drench young stock
- Bucks introduced to breeding does
Goats and sheep are susceptible to similar diseases and so have similar husbandry costs. Dipping for external parasites, such as sucking and biting lice, is essential and should occur in February (Horgan, 1979; Batten, 1979c). Drenching is also necessary to control for internal parasites (Horgan, 1979). Goats are susceptible to footrot, although Horgan (1979) did not find this a problem.

The commercially productive life of a feral doe is not well documented; however, for culling purposes a 7 year old angora is said to be equivalent to a 5 year old ewe (Anon, 1982a). If a feral doe is assumed to have a similar life expectancy to an angora doe and only young ferals are selected for the weed control program, then a productive age will not be an issue in this study. This is because the majority of goats required for gorse control are needed for less than two years.

(ii) Specific Requirements.

Being susceptible to cold, rain and wind, goats suffer from a higher death rate than is normal in sheep. The death rate in kids can also be quite high if there is not adequate shelter (Horgan, 1979). A 10 per cent death rate was used in this study, based on experience at Ballantrae (Clark and Rolston, 1983, pers. comm.). Ritchie (1982) also used this death rate in estimating gross margins for goats controlling gorse.

Since goats are considered to be a noxious pest, they are required to have registered ear tags so that they can be clearly identified from wild goats (Batten, 1979c; Horgan, 1979).

Sheep yards are not adequate for handling goats since goats are difficult to contain. Cattle yards are more suitable (Horgan, 1979). Alternatively, cheap make-shift yards with height approximating cattle yards would be adequate.

When using goats in gorse control, adequate fencing must be provided (Batten, 1982). Electric fencing has proven to be successful in containing goats (Batten, 1979b) and because it is relatively cheap, its use is quite common. Given there are existing fences, only one electric wire is necessary at approximately 5 to 10 centimetres off the ground (Horgan, 1979; Rolston, 1983, pers. comm.). This wire will prevent goats pushing under the fence, the usual method of 'testing' fences (Horgan, 1979).

(iii) Grazing Management.

A maintenance stocking rate of goats is expected to be a good form of long-term gorse control (Rolston, 1983, pers. comm.). Vere (1979) suggested a goat maintenance requirement for blackberry control of 1.25 goats per hectare. While no research has been done to assess the goat maintenance rate required for gorse control in New Zealand, Rolston (1983, pers. comm.) suggests that a rate of 2 goats per hectare would be appropriate.
Goats grazed for gorse control can be either set stocked or rotationally grazed. The best method is not clear. Batten (1982) suggests that mob stocking of goats leads to more spectacular weed control but that over a larger area and in the long term, both set stocking and mob stocking will give the same results. Goats prefer to roam and choose a varied diet, so could suffer stress and health problems in a confined mob stocking situation. (Batten, 1982). Morgan (1979) on the other hand suggests that the rotational grazing of goats with sheep is more practical and desirable for management purposes. The Ballantrae trial only assessed set stocking management and found this method to work well. The Loburn trial on the other hand assessed both methods and found there were differences between the two. Rotationally grazed treatments gave better control of gorse; however, due to burning problems, the grazing treatments did not commence with identical gorse densities, which made comparisons difficult (Radcliffe, 1983, pers. comm.). Replicates at Loburn are being assessed to determine whether this result is correct. The current impression is that set stocking is adequate for areas infested at a low density and that rotational grazing may be better for controlling higher density gorse (Radcliffe and Rolston, 1983, pers. comm.). The major disadvantage with rotational grazing is that a higher fencing cost is incurred. The majority of data available is relevant to gorse at lower densities; set stocking is therefore assumed adequate for this condition.

(2) Sheep.

Sheep management has been well researched and recommended practices are widely used. An example of this information was given by Owen (1976). Thus, a detailed discussion of this is not presented here, but rather an outline of the sheep enterprise.

The sheep enterprise for both the goat and chemical control programs evaluated in this study was assumed to involve the following management program:

- Romney ewes breed their own hogget replacements and all wether and surplus ewe lambs are sold fat or store before Christmas,
- all shearing and crutching is done by contract,
- animal health includes drenching, vaccine and dip,
- rams are included in the flock at 3 per cent and have a productive life of four years,
- all ewes are culled at 5 years,
- wool and lambing percentages are directly related to the quantity of feed on offer. Typical production for the Ballantrae district is 4.50 kg of total wool clip per ewe and 90 per cent lambing. Of the lambs sold, 50 per cent are sold as prime while 50 per cent are sold as stores.
3.3.2 Marketing

The potential salable products from a breeding feral flock include meat, skins, progeny sold as first cross angora, progeny sold for scrub control, and cashmere. A first and second cross angora wether enterprise is also a possibility for scrub control, with returns coming from cashgora production. The increased demand for feral goats in scrub and weed control, improved market prospects for cashmere and cashgora, and the influence of the newly formed angora industry has meant that currently high returns from goats used in scrub control are possible. However, some of these markets are in the early stages of development in New Zealand and this is currently creating artificially high prices which cannot be sustained in the long term. Therefore, in analysing the economics of gorse control, both current and expected long-term economic implications were included.

(1) Goat Meat.

The marketing of goat meat is based on disposing of New Zealand's excess feral goat population (Sheppard and O'Donnell, 1979). Traditionally feral goats have been harvested by farmers looking to control their numbers and to obtain some monetary return. Also, because feral goats are regarded as noxious animals of low value, goat meat marketing systems tend to be poorly developed. The problems facing this industry include the limited season for which killing works will accept goats for slaughter (Ritchie, 1979). This season does not coincide with the ideal time for finishing goats, thus, goat meat from New Zealand becomes less competitive in export markets resulting in poorer prices. The limited season for goat killing also creates a problem in continuity of supply to export markets.

The markets demanding goat meat occur in less developed regions of the world such as the Caribbean and Fiji (Sheppard and O'Donnell, 1979). These countries have a limited capacity to pay for goat meat and so the export of goat meat realises a relatively poor return compared to lamb and beef. While there appears to be a good potential for the sale of goat meat, the price is expected to remain relatively low (Hughes et al, 1982).

(2) Skins.

New Zealand exports approximately 80 per cent of its goat skins, with the remaining 20 per cent being processed into leather by domestic firms (Sheppard and O'Donnell, 1979). Fluctuations in skin prices make costing difficult (Morriss, 1979). Skins can be either separately priced or included in the goat price to killing works (Batten, 1979; Ritchie, 1979). In this study the value of skins was included in the price paid for feral goats as meat.
(3) **Feral Does Crossbred to Angora Bucks.**

Increased demand for mohair has caused relatively high angora prices and hence high returns to angora stud breeders (Ritchie, 1981). The demand for angora goats in New Zealand cannot be met by current supply. This situation can only be eased by increasing stock numbers through breeding since importing these animals is prohibited. This has opened up the opportunity for cross-breeding feral does with angora bucks to obtain first-cross angora does. Current prices for first cross angora does in the North Island range from $80-$100 per head (Moorhouse, 1983, pers. comm.). Potential returns for this type of feral goat enterprise are high. While pure angora stock are in short supply these prices are likely to be sustained; however, this will not be the case in the longer term once supply is adequate. First cross doe prices can then be expected to be similar to progeny sold for meat.

(4) **Cashmere.**

Cashmere production is a new industry to New Zealand and appears to have a good potential (Parkinson, 1983, pers. comm.). The cashmere fibre is down in the 15 to 19 micron diameter range and is evident in most feral animals to varying degrees (Rennie, 1982). This fibre is finer than mohair and current prices range from $40 to $130 per kilogram depending on the quality of the cashmere. If cashmere producing herds are to be established from feral goats, a high selection ratio of one in twenty goats is required due to the variation of cashmere in these goats (Parkinson, 1983, pers. comm.). Therefore, a large supply of feral does and available selection time are required before a cashmere herd can be established.

The variation of cashmere prices within a year is directly related to the down colour and fibre diameter, with the white fibre at 15 microns obtaining the highest price. A great deal of genetic gain can be achieved if farmers approach cashmere production seriously (Parkinson, 1983, pers. comm.). However, this takes time and may not suit a gorse control program where the main objective is a return to full sheep production.

The long-term price for cashmere appears stable since potential demand is far greater than supply (Moyland, 1983, pers. comm.).

(5) **Cashgora.**

Cashgora is a fibre with a diameter between 19-23 microns, produced from first and second cross angora goats. This diameter falls between the finer cashmere and the coarser mohair. Cashgora is a market recently established in the world agricultural fibre industry and hence long-term stability has not been reached. This fibre is graded into three classes (Cashgora A, Cashgora B and Cashgora C), depending on the quality of fibre and the age of the animal when the fibre was cut (Woodward, 1983, pers. comm.). Current New Zealand prices for these classes are:
Cashgora A  $70/kg  
Cashgora B  $30/kg  
Cashgora C  $14.25/kg  

Fibre from animals older than 12 months is classed as Cashgora C. This cashgora grade was used in this study to assess returns for fibre from first and second cross angoras.

The long-term price for cashgora may decline, but to what extent is difficult to ascertain due to the infancy of the market (McDonald, 1983, pers. comm.).

(6) **Sheep Products.**

Sheep products include lamb, mutton and wool. These items are marketed by Producer Boards within New Zealand and are largely subject to a minimum price scheme designed to protect farmers from the fluctuations and low prices within these markets. Since these markets are well established and details of them are commonly known, no detailed description was presented in this study; however, price fluctuations in these markets were taken into account in assessing the sensitivity of the model's results.

### 3.3.3 Costs and returns for goat and sheep grazing.

(1) **General Costs and Returns.**

Since the options open to farmers concerning the type of feral goat enterprise are numerous, four types were selected and assessed in this analysis. The four were chosen as being representative of the options available. The four enterprise types are:

**OPTION 1**: dry feral does and wethers with income from cashmere production,

**OPTION 2**: first and second cross wethers with income from cashgora production,

**OPTION 3**: self replacing feral doe herd with surplus kids sold for meat,

**OPTION 4**: feral does crossed to angora bucks with all first cross kid does sold to angora breeders and wethers for scrub control. Replacement feral does are bought-in each year.

The current financial costs and returns of these four goat enterprises are given in Appendices 2 to 5. These gross margins, although estimates, account for all the financial aspects necessary to assess the economics of gorse control.
Topdressing is required for both goat/sheep and chemical methods of gorse control and was costed within the analysis. Topdressing rates were taken from Rennie (1979) and are based on M.A.F. recommendations. These costings are listed in Appendix 7.

(2) Costs Specific to this Study.

For the sheep enterprise, a self replacing Romney flock was included in the analysis. The current returns from this enterprise are listed in Appendix 6. This flock was assumed to be run as part of the farm's total sheep enterprise. Thus, in the financial assessment it was assumed that replacement lambs from this flock were carried elsewhere on the farm with replacement hoggets coming back into the gorse control flock.

As mentioned, goats require adequate fencing. Assuming a permanent fence exists, a one electric wire addition is all that is necessary for the 30 hectares. The costings and associated assumptions for this fence are listed in Appendix 8.

3.4 Chemical and Mob Stocking Approach

3.4.1 Management.

(1) Chemical.

Gorse is best sprayed when it is less than 1 metre in height. If higher than a metre, the stand should be burnt and the regrowth sprayed. Burning could be difficult if there is not a thick gorse stand, in which case spot spraying may be the only alternative on non-arable hill country. This analysis assumed that a burn was necessary during the chemical program.

The chemical most widely used and recommended for spraying is 2,4,5-T. Other chemicals that can be used in mixtures with 2,4,5-T are Diquat, Dicamba or Picloram (Mecklah, 1981). For simplicity and because 2,4,5-T is the cheapest and most cost efficient chemical (Rolston, 1983, pers. comm.), only this chemical was costed in the chemical program.

The most appropriate time to spray gorse is after flowering but before mid-January, although spraying will have an effect any time of the year. Daily conditions will also affect the action of 2,4,5-T. This chemical enters the plant through the leaves so foliage uptake is required (Mecklah, 1981). This occurs best during periods of mild temperature and moderate to high humidity.

To ensure a gorse bush is killed it must be completely covered with the spray. Thus, the conditions of spray application are important for a good kill of the gorse stand. Spot spraying is potentially the best spray method to kill gorse because full bush cover is possible.
Blanket spraying by air will not necessarily gain full cover. However, spot spraying becomes expensive at high gorse densities since contractors charge on an hourly basis. In these cases it is more economical to blanket spray. Therefore, blanket spraying is usually the first chemical application in the spray program. This is followed in subsequent years with a lighter blanket spray until the gorse is adequately controlled. When only a maintenance spray is required to check further gorse regeneration, blanket spraying can be carried out either by fixed wing aircraft or helicopter, the latter being considered better (Mecklah, 1981).

(2) Mob Stocking.

Mob stocking with sheep is usually practised in conjunction with a spray program so that maximum grazing pressure can be applied to the gorse. A stocking pressure of 200-250 sheep per hectare is necessary to graze and trample gorse seedlings and prevent reversion. In this study, the sheep required for mob stocking were assumed to be available from the supply of sheep on the farm. Thus extra sheep for mob stocking were not purchased. Similarly, no alterations were expected to the farm returns due to mob stocking.

Mob stocking can also be used prior to the initial burn. This makes the gorse stand open out and become more vulnerable to fire. Alternatively, a light blanket spray of 2,4,5-T several months prior to burning ensures a hot burn and a greater kill of gorse plants (Rolston and Talbot, 1979). The blanket spray before burning is more commonly used by farmers and is also recommended by the M.A.F. so was assumed to be part of the chemical control method assessed in this study.

3.4.2 Cost and returns for chemical control.

Estimating the cost of chemical application is made difficult by the numerous spray program recommendations. These recommendations vary with the density of gorse to be handled and the experience of the advisor. One recommendation forms the basis of this analysis and is outlined in Appendix 1. This recommendation is representative of hill country gorse spray programs and was developed from experience on a farm-sized redevelopment project at Wanganui (Rennie, 1979). The chemical application is lighter than rates traditionally recommended but has been found adequate. Chemical and spraying costs are listed in Appendix 9.
CHAPTER 4

THE MODEL

4.1 Introduction

Any system being simulated has certain characteristics that affect the approach to modelling. Important characteristics of this system are:

(a) limited data to guide model construction,

(b) the numerous enterprise alternatives for the goat/sheep method, with many in the process of short-term change.

To accommodate the uncertainty associated with these aspects of the system, model construction was designed to provide flexibility of analysis. Model experimentation and sensitivity analysis were then used for assessing the economic differences between the chemical and the goat/sheep grazing methods of controlling gorse.

This chapter describes the components of the system, the physical constraints in building the model, model construction and finally an outline of how the model operates.

4.2 Model Evaluation

The process of model evaluation largely determines the confidence placed in the generated results and the value of the analysis for decision support. Hence, it is an important stage within the analysis. Model evaluation is made up of two distinct aspects: verification and validation (Dent and Blackie, 1979). Fisherman and Kivak (1967) give a concise definition of these terms:

verification - insuring that the model behaves the way the experimenter intends.

validation - testing the agreement between the behaviour of the model and that of the real system.

Since model evaluation occurs both during model construction and at the completion of model building, the description of model evaluation will be mentioned within this chapter.

The methods used for validation vary depending on the model and the modeller. There are both subjective and objective tests. Subjective tests are equally as important as objective tests (Dent and Blackie, 1979), as models often deal with the unknown where only opinion can guide validation. Due to the lack of data within the system being
studied, subjective tests were used quite extensively during model construction. Of the tests that can be applied for verification and validation, as listed by Shannon (1975) and Van Horn (1971), the following are seen to be most appropriate to this model:

(a) Use common sense and logic in building the model, and assess validity during model development,

(b) Use experts and research results closely related to the system to guide modelling,

(c) Use simple empirical results to assess hypotheses and assumptions where possible,

(d) To gain confidence in the performance of the model, assess the model using test data during the debugging stage,

(e) Use subjective tests to assess results wherever possible,

(f) Perform sensitivity analysis on the model to assess whether it performs as expected.

4.3 The System's Structure

4.3.1 Data availability.

The structure of a model can be influenced strongly by the data availability and, in this system, data were quite limiting. For the goat/sheep method of controlling gorse there were, as previously mentioned, two trial sites generating data. These were at Ballantrae near Woodville, run by the D.S.I.R., and Loburn (North Canterbury) operated by the M.A.F. The major objective of research at these sites was to assess the effectiveness of goats and sheep controlling gorse under different grazing combinations.

Both trials have provided data on goat grazing for gorse control, but the methods of measurement differ. Gorse at the Ballantrae trial was measured on specific sites with only height changes recorded. The Loburn trial, on the other hand, has data available on gorse height, density and volume, and percentage gorse cover changes. Unfortunately, the trials did not commence with the same gorse density after the initial burn and so direct comparisons between the two are difficult.

The Ballantrae trial involved set stocking of goats and sheep on gorse, while the Loburn trial involved both set stocking and rotational grazing treatments. The goat to sheep grazing ratios assessed in the Ballantrae trial were 0 per cent, 33 per cent, 66 per cent and 100 per cent while at the Loburn trial the ratios were 0 per cent, 50 per cent and 100 per cent. The assumed grazing equivalent of a goat was initially set at 0.5 S.U. in the Ballantrae trial, while the Loburn trial equated two goats to one sheep. In both trials this ratio was changed soon after the commencement of the trial due to the problem of underutilizing pasture. The Ballantrae trial altered the general
stocking intensity from 9 S.U. per hectare to 11 S.U. per hectare 18 months after the commencement of the trial and again 9 months later when a goat was equated to 0.33 S.U. The trial at Loburn increased the grazing pressure by 15 per cent, 11 months after the commencement of the trial. These stocking rate alterations meant that the grazing pressure of goats on gorse altered and any function relating gorse decline to goat grazing pressure could only be objectively estimated based on the early period of both trials.

Although gorse control was approached differently at each trial, the scientists involved felt the general conclusions related to the ability of goats to control gorse were similar in both cases (Radcliffe and Rolston, 1983, pers. comm.). Hence, subjective judgement based on both trials was assumed to be useful for this model.

Another data difficulty was that neither trial treatments were replicated at the time of modelling. Thus, statistical analysis was restricted since only one set of observations was available for each treatment.

The main source of data used for model development was the Ballantrae trial since more comprehensive data were available. For example, indications of the clover benefit due to goat grazing were evident at the Ballantrae trial but not at the Loburn trial. Also, the Ballantrae trial had been in progress for a longer term than the Loburn trial, which meant more experience in observed relationships within the system was evident. Where there were deficiencies in the Ballantrae trial data, the Loburn trial data were used as a guide.

The treatments in the Ballantrae trial were described in research publications as proportions of goats or sheep in the total grazing pressure (Clark et al., 1982; Rolston et al., 1981a). In this study these treatments are referred to on the basis of the number of goats or sheep grazed per hectare. This approach coincides with the hypothesis that the rate of gorse control is directly related to the number of goats grazed per hectare.

Data are also scarce on the effects of chemicals on gorse and subsequent pasture damage. While 2,4,5-T has been used quite extensively for gorse control, little quantitative data suitable for determining relationships between chemical treatments and gorse control are available. Similarly, there is a lack of quantitative data on the effect of 2,4,5-T on clover production. Therefore detailed modelling of the chemical option of gorse control was also difficult given the data availability.

4.3.2 Deterministic model.

A major area of uncertainty in many agricultural systems is the effect of climate. As gorse growth, however, was felt not to be affected greatly by climatic variation, climate would appear to have limited effect on the system being studied (Clark and Rolston, 1983, pers. comm.). Also, any influence that does occur will similarly affect
the chemical and goat/sheep method and hence it was assumed unnecessary to allow for stochastic climatic effects within this model.

The two trial seasons (1979/80 and 1980/81) at Ballantrae experienced average climatic conditions and so the trial results are seen as typical for normal seasons (Clark, 1983, pers. comm.).

Uncertainty related to other aspects of the system such as prices and rates of pasture development is handled through sensitivity analysis.

4.3.3 The general system.

A general structure diagram of the system being studied is given in Figure 13. The system can be modelled in two distinct sub-systems; a goat/sheep sub-system, and a chemical control sub-system. Both sections are brought together in the economic analysis for comparisons to be made.

Conceptually, the goat/sheep system comprises four components. The first involves the relationships between the goat grazing pressure and the rate of gorse control. Different levels of goat grazing pressure give rise to different clover content within the pasture. This relationship is the next component of the system. Goats and sheep have different grazing preferences and, depending on the pasture composition, are either complementary or competitive grazers. The goat/sheep grazing component involves the degree of complementarity or competitiveness and the quantity of pasture on offer. The animal production component comprises the relationships between animal production and feed availability.

The chemical control system is represented in a similar manner. Chemical is applied in varying quantities throughout the redevelopment phase. This aspect of the system is largely dependent on the spraying operator and the levels of gorse present in the pasture. However, for a specific guide, a M.A.F. spray recommendation was used. Chemical spraying, especially 2,4,5-T, has detrimental effects on clover production and thus indirectly affects grass production. The next component deals with these relationships. The animal production component involves animal production levels given the number of animals carried and the available pasture production.

4.4 Time Interval

The time step of a model is largely dependent on the availability of data and the appropriate level or detail of modelling. A monthly time interval would seem ideal but due to the limited data available and the time periods in which they were collected, a time step of a quarter (3 months) was chosen. It was felt that quarterly data would still detect the seasonal factors that influence gorse control. This time stepping interval was reassessed during model development.
FIGURE 13:

A STRUCTURE DIAGRAM OF THE GENERAL MODULES

THAT MAKE UP THE SYSTEM

GOAT / SHEEP METHOD FOR GORSE CONTROL

GORSE / GOAT RELATIONSHIP

PASTURE AND CLOVER CHARACTERISTICS

GOAT / SHEEP GRAZING COMPLEMENTARY

ANIMAL PRODUCTION

ECONOMIC ANALYSIS AND COMPARISON

CHEMICAL METHOD FOR GORSE CONTROL

CHEMICAL APPLICATION

PASTURE AND CLOVER CHARACTERISTICS

ANIMAL PRODUCTION
4.5 Modelling the Goat/Sheep Method

4.5.1 The goat and gorse relationship.

Given the preference of goats for gorse in diet selection, it was hypothesised that the rate of gorse control was a function of goat grazing pressure. The only assessment of the rate of decline of gorse due to goat grazing at Ballantrae was made using gorse height. Figure 14 indicates the height variation under different goat grazing pressures. Generally, the heavier the goat grazing pressure, the greater the decline in the height of gorse.

Results from the Loburn trial were assessed to ascertain whether gorse height was an indicator of effective gorse cover. A simple linear regression was estimated using the part of the Loburn trial that most closely represented the Ballantrae trial. That is, the first two years data with set stocking management. The following result was obtained:

\[ y = -4.31 + 1.42 \times \]  
\[ (3.24) (0.16) \]

\[ R^2 = 91.2 \text{ per cent, adjusted for D.F.} \]

where:  
\[ y = \text{effective gorse cover (}) \]
\[ x = \text{gorse height (cm)} \]
\( ( ) = \text{standard error} \)

This regression indicates a strong linear relationship between gorse height and effective gorse cover at the Loburn trial. The relatively high adjusted R-square also indicates the good predictive power of this estimate. In the absence of other evidence, it was assumed that this same relationship holds for the Ballantrae trial.

To add validity in simulating effective gorse cover, subjective estimates by D.S.I.R. scientists were also taken into account. Their estimates, shown in Figure 15, indicated that effective gorse cover would be minimal after 2 years of goat/sheep grazing. They felt there was little difference in the rate of gorse control between 18 and 12 goats per hectare (100 per cent and 66 per cent goats). The treatment of 6 goats per hectare (33 per cent goats) showed slightly less control while 9 ewes per hectare (100 per cent sheep) showed no control.

Effective gorse cover estimates for a quarterly time step were made by using the height variation observations in Figure 14 and the subjective estimates of Figure 15; however, a few alterations to the height information had to be made. These alterations are listed below with the results shown in Figure 16.

(a) From Figure 15, effective gorse cover changes were identical for 18 and 12 goats per hectare. The heavier goat stocking rate would be expected to give greater pressure on gorse height; however, initially this was not the case between the two treatments, as seen in Figure 14. Since an indication for a quarterly time step was
FIGURE 14: GORSE HEIGHT MEASUREMENTS FROM THE BALLANTRAЕ TRIAL
FIGURE 15: EXPECTED EFFECTIVE GORSE COVER CHANGES TO VARIOUS GOAT GRAZING RATES (Clark & Rolston, 1983)
needed and the 18 goats per hectare treatment gave the expected result, the 12 goats per hectare observations were ignored.

(b) It would appear from Figure 15 that gorse was brought under effective control approximately two years after goat grazing commenced. This being the case, the gorse height observations had to be extended for a whole two year period. Data were available from the trial for the 0 goats per hectare treatment; however, due to grazing rate changes, data had to be extrapolated for 6 and 18 goats per hectare treatments. The extrapolation was done with the knowledge that effective gorse cover declined to zero after two years under the 18 goats per hectare treatment and the 6 goats per hectare treatment to 1 per cent effective cover over the same period (see Figure 14). The extra data points required were then estimated by relating the required height decline to the gorse growth pattern given in Figure 1. The extrapolated points from August 1980 to April 1981 are shown in Figure 16.

(c) From the regression equation (1) effective gorse cover is zero when the approximate height of gorse plants is 3cm. At approximately 6cm, the effective gorse cover is 1 per cent. Thus the 6 goats per hectare treatment converges to 6cm and the 18 goats per hectare treatment to 3cm.

(d) The gorse height observations between October 1978 and April 1980 were too sparse to establish quarterly estimates. Values were therefore adjusted on the basis of the gorse growth pattern given in Figure 1. The extrapolated values are plotted in Figure 16 and allowed quarterly observations to be estimated for all treatments.

Quarterly estimates of effective gorse cover were obtained by relating the starting and finishing gorse heights of the various treatments to the respective starting and finishing effective gorse cover estimates. The quarterly variations in height were then calculated as a direct linear relationship indicating effective gorse cover. The estimated quarterly effective gorse cover changes are listed in Table 1. From these figures effective gorse cover changes were simulated.

By plotting the three observations from each quarter and then estimating a curve by eye through these three points, a goat stocking rate relationship for each quarter could be established. These relationships form the basis for estimating the effective gorse cover in each quarter for the first two years, for any goat grazing proportion within 9 S.U. per hectare. The relationships for July 1979 and October 1979 are given in Figure 17 and 18 respectively.

There is inadequate information available to ascertain when each goat treatment will control effective gorse cover to zero. Subjective estimates are only available for the 18 goats per hectare treatment shown in Figure 15. To allow the 6 goats per hectare treatment estimates to be included in the model, it is assumed that zero effective gorse cover is reached one quarter after the 18 goats per hectare case.
FIGURE 16: RECORDED AND EXTRAPOLATED GORSE HEIGHT ESTIMATES
FIGURE 17: ESTIMATED RELATIONSHIP AFTER THE FIRST QUARTER BETWEEN THE PROPORTION OF GOAT GRAZING AND EFFECTIVE GORSE COVER

July 1979 Quarter: 1

FIGURE 18: ESTIMATED RELATIONSHIP AFTER THE SECOND QUARTER BETWEEN THE PROPORTION OF GOAT GRAZING AND EFFECTIVE GORSE COVER

October 1979 Quarter: 2
4.5.2 The grazing and pasture relationships.

The aspects of this part of the system to be considered are:

(a) The effect of different goat grazing pressures on the clover content of the pasture,

(b) The effect of different goat/sheep grazing combinations on pasture production,

(c) The effect of changing pasture composition on animal production.

These aspects affect the sheep production during gorse redevelopment. Goats are assumed primarily to be of value for gorse control and any financial return is of secondary benefit. Given this assumption, the above aspects were considered only with respect to estimating sheep production.

<table>
<thead>
<tr>
<th>Time (Quarter)</th>
<th>0 GOATS</th>
<th>6 GOATS</th>
<th>18 GOATS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Per Hectare</td>
<td>Per Hectare</td>
<td>Per Hectare</td>
</tr>
<tr>
<td>0</td>
<td>5.0</td>
<td>5.0</td>
<td>5.0</td>
</tr>
<tr>
<td>1</td>
<td>3.9</td>
<td>1.8</td>
<td>1.4</td>
</tr>
<tr>
<td>2</td>
<td>2.9</td>
<td>1.8</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>9.3</td>
<td>3.1</td>
<td>2.4</td>
</tr>
<tr>
<td>4</td>
<td>14.0</td>
<td>4.1</td>
<td>2.9</td>
</tr>
<tr>
<td>5</td>
<td>14.4</td>
<td>2.9</td>
<td>1.6</td>
</tr>
<tr>
<td>6</td>
<td>13.3</td>
<td>2.4</td>
<td>0.9</td>
</tr>
<tr>
<td>7</td>
<td>16.8</td>
<td>1.6</td>
<td>0.4</td>
</tr>
<tr>
<td>8</td>
<td>21.1</td>
<td>0.9</td>
<td>0.0</td>
</tr>
</tbody>
</table>

There is obviously a threshold goat grazing pressure where gorse cover remains static at its initial level; however, more research data are required before this threshold level can be determined. Therefore, the effective range of goat treatments that can be tested by this model is between 6 and 18 goats per hectare (33 per cent and 100 per cent goats grazing in a 9 S.U. per hectare situation where a goat is taken as 0.5 S.U.).
Over the first two years of the Ballantrae trial, there were both measurable and visual differences in the percentage of clover on offer between the different grazing treatments (Clark and Rolston, 1983, pers. comm.). Figure 19 indicates the difference in per cent clover on offer. The result is as generally expected; the higher the proportion of goats used to control gorse, the less heavily grazed was the clover.

Given that clover production varies with the proportion of goats, it might be expected that pasture production would vary in response to changed nitrogen levels. However, on inspecting the pasture production figures for the first two years of the Ballantrae Trial given in Figure 20, there appeared to be no significant response in pasture production. Pasture production from all treatments followed the expected seasonal pattern without any obvious differences occurring. Statistical procedures testing for significant differences cannot be applied because there are no replicates. Therefore, subjectively it was assumed that no differences occur between treatments and no pasture production changes need to be allowed for. Differences in sheep production between treatments would therefore appear to be a function of differences in pasture composition, in particular clover content.

To model this aspect of the system Krause (1983) developed and described a detailed procedure designed to stimulate the relationship between pasture composition and diet composition of sheep and goats. In this procedure the diet similarity coefficient 'S' is estimated as a function of gorse cover, clover on offer and the percentage of thistles in the diet. The estimated 'S' value is then used in conjunction with the sheep/goat ratio and known pasture composition details, to estimate the size and composition of diet for both sheep and goats. The main reason for attempting to model the extent of complementary/competitive grazing between sheep and goats is to predict the changing clover content in the sheep diet and consequent changes in sheep production; however research information indicating the quantitative relationships between diet composition and sheep production parameters is limited and consequently such a detailed simulation procedure is of little immediate value until further research results are available (Thompson, 1983, pers. comm.).

Instead a more simplistic approach was adopted for this study based on the actual Ballantrae trial results. Since ewe live weights were available from the Ballantrae trial these figures were used to indicate any benefit from increased clover production. The ewe live weight variations are shown in Figure 10 (see section 2.2.3 (2)). While there are no replicates, and no statistical analysis of significance can be made, it would appear from the data shown in Figure 10 that over the first two years of the trial only the 3 sheep per hectare treatment (12 goats per hectare) responded to increased clover and that was only in the second year. There appears to be little difference between any of

---

7. The subroutines necessary to use the procedure described above are retained in the model to allow for the improvement of research knowledge in the future, when this method of monitoring pasture production and consumption would become appropriate.
FIGURE 19: PERCENTAGE CLOVER PRESENT IN THE PASTURE AT THE BALLANTRAEB TRIAL

CLOVER PERCENTAGE

MONTHS

OCT DEC FEB APR JUN AUG OCT 1980

FEB APR JUN AUG OCT DEC FEB APR JUN AUG 1981

18 goats/ha
12 goats/ha
6 goats/ha
0 goats/ha
FIGURE 20: PASTURE PRODUCTION FROM THE BALLANTRAЕ TRIAL TREATMENTS

[Diagram showing pasture production from different treatments with labels for 18 goats/ha, 12 goats/ha, 6 goats/ha, and 0 goats/ha.]
the treatments in the first year. There also appears to be little difference between the ewe live weights of treatments 6 and 9 sheep per hectare (6 and 0 goats per hectare) in the second year. It is assumed then that any clover benefit is only experienced in the second year of gorse grazing control and by grazing proportions containing less than 6 sheep per hectare grazing pressure (greater than 6 goat per hectare) (Thompson, 1983, pers. comm.).

From this assumption and given ewe production to live weight relationships listed below, an estimate of sheep production parameters can be made. The sheep production equations are rules of thumb obtained from Thompson (1983, pers. comm.) and deal with expected lambing percentages and total wool clip per ewe.

\[
A = (2 \times B) + 5
\]  

(3)

where:

\[A = \text{number of lambs tailed},\]
\[B = \text{ewe live weight at mating}.\]

\[C = 0.1 \times D\]

(4)

where:

\[C = \text{total wool clip per ewe},\]
\[D = \text{mean annual live weight per ewe}.\]

Equation (3) outlines the relationship between the live weight of a ewe at mating to the number of lambs marked, while equation (4) gives the relationship of mean annual ewe live weight to total wool clip per ewe. Given these relationships, the results for the second year of ewe live weights are listed in Table 2. These results also indicate that the difference in animal production only occurs between the 3 and 6 sheep per hectare treatments. However, there is a problem in that the animal

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>LAMBING PERCENTAGE</th>
<th>KG WOOL PER EWE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Sheep per hectare</td>
<td>114.3</td>
<td>5.56</td>
</tr>
<tr>
<td>(12 Goats per hectare)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6 Sheep per hectare</td>
<td>108.3</td>
<td>5.12</td>
</tr>
<tr>
<td>(6 Goats per hectare)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 Sheep per hectare</td>
<td>108.9</td>
<td>5.21</td>
</tr>
<tr>
<td>(0 Goats per hectare)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
production parameters at the base level are higher than expected normal levels for the district. The equivalent district animal parameters would be 90 per cent lambing and a 4.50kg wool clip per ewe (Clark and Rolston, 1983, pers. comm). These differences could be due to the smaller size and better conditions on the experimental treatments. To overcome this discrepancy the trial ewe live weights were adjusted to expected district levels. The ewe live weight differences between 3 and 9 sheep per hectare treatments were maintained except that the 9 sheep per hectare ewe live weight was lowered to the expected district level. The resulting sheep production parameters in the second year of the model are listed in Table 3.

TABLE 3

Animal Production Parameters Used for the Second Year in the Model

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>LAMMING PERCENTAGE</th>
<th>KG WOOL PER EWE</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Sheep per hectare</td>
<td>95.6</td>
<td>4.84</td>
</tr>
<tr>
<td>(12 Goats per hectare)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 &amp; 6 Sheep per hectare</td>
<td>90.0</td>
<td>4.50</td>
</tr>
<tr>
<td>(6 &amp; 0 Goats per hectare)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Since data were restricted to the three grazing treatments (3, 6 and 9 sheep per hectare), results from the treatments with the highest proportion of goats (3 sheep per hectare) were taken as the maximum improvement expected in sheep production. Grazing rates between 12 and 18 goats per hectare, therefore, were assumed to achieve the same sheep production improvement. A scaling of sheep production improvement occurs between 3 and 6 sheep per hectare (6 to 12 goats per hectare). Here a direct linear relationship is again assumed for the production parameters. For example, a sheep ratio of 50 per cent (9 goats) will obtain half of the maximum increase in animal production benefit from clover improvement.

Another aspect to be considered is the benefit of clover after the grazing ratios have been changed. It was assumed that a benefit will only remain for the first year after the change and only half the benefit will occur in this year.

Figures 21 and 22 illustrate these assumptions and how the model was constructed to deal with them. For both the ewe wool clip and the lambing percentage, the maximum benefit is achieved in the second year, halved in the following year and back to normal in the third and subsequent years.
FIGURE 21: THE EWE WOOL PRODUCTION IN RELATIONSHIP TO VARYING LEVELS OF GOAT GRAZING

Top level based on 12 goats/ha (3 sheep/ha)
Base level set by 0 and 6 goats/ha (9 and 6 sheep/ha)

FIGURE 22: THE LAMBING PERCENTAGE IN RELATIONSHIP TO VARYING LEVELS OF GOAT GRAZING

Top level based on 12 goats/ha (3 sheep/ha)
Base level set by 0 and 5 goats/ha (9 and 6 sheep/ha)
4.6 Modelling of the Chemical Method

Modelling of the chemical option had two major problem areas:

(a) alternative spray programs that can be undertaken,
(b) the lack of quantitative data relating the spraying of 2,4,5-T to effects on pasture production.

The first problem is reduced by using the M.A.F. spraying program listed in Appendix 1. This also guided the costings of chemical application.

While there is a lack of data to guide the precise assessment of 2,4,5-T effects on clover and pasture production, there is a wealth of experience of using this chemical for gorse control. This subjective information guided the assessment of pasture recovery rate during the redevelopment of gorse infested areas. A small survey was taken of M.A.F. advisors who have had experience advising spray options for gorse control and have observed the results. Table 4 lists their expectations of the potential carrying capacity of the land while it is under a spray program for the control of gorse. These expectations reflect both the extent of clover and pasture damage as well as the recovery pattern. These expectations are the best information available upon which to base the economic assessment of using chemicals to control gorse.

<table>
<thead>
<tr>
<th>ADVISORS</th>
<th>YEAR</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>0.33</td>
<td>0.66</td>
<td>(gradual increase)</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>0.25</td>
<td>0.50</td>
<td>(gradual increase)</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>0.60</td>
<td></td>
<td>(gradual increase)</td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>0.60</td>
<td>0.85</td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The figures given in Table 4 represent the proportion of optimum carrying potential of the land. Hence, at a 9 S.U. per hectare potential, 0.33 would represent 3 S.U. per hectare.

These variations in the rate of pasture recovery were assumed to represent the range of development rates that can be expected. It was assumed that the same chemical spray program is used and thus this range of development reflects the variation in management skills with the best management skills obtaining the quickest development rate.
4.7 Modelling of the Economic Analysis

The economic analysis was based on generating a development budget for each control option within the partial analysis framework. From this development budget, constructed in present dollar values, the cash flow, break-even point, internal rate of return (IRR), net present value (NPV) and benefit-cost ratio were calculated. In calculating the NPV and benefit-cost ratios, a real interest rate was appropriate since all figures within the development budget were expressed in current values. The value of 5 per cent was taken as the appropriate current real interest rate.

The development budget was also calculated without allowance for borrowed funds or taxation. Taxation and financial requirements are dependent on each particular farm situation. Allowing for a particular taxation rate and amount borrowed would restrict the results to those farmers with that defined financial and taxation situation. The detailed development budget however, should allow farmers or consultants to assess the implications of specific financial and taxation constraints. It is also hypothesised that any financial or taxation restriction would equally affect both gorse control options.

The model generates the development budget until the year in which a steady state income is first reached. At this stage the development is considered to be complete. Since the control of gorse is a long-term program for both the goat/sheep and the chemical methods, a steady state in this analysis is assumed when the effective cover of gorse is zero and the pasture production has returned to normal expected levels. The steady state financial situation includes a gorse control maintenance cost for both situations.

The calculation of IRR, NPV, and the benefit-cost ratio include the final annual steady state income discounted as a perpetual annuity as recommended by both Chisholm and Dillon (1971) and Hardaker et al (1971). An alternative would be to assume that the land and livestock are sold once the land is redeveloped. This ensures capital gain of the improved land is included in the investment analysis. If the market value for land is determined in a free market, as could be assumed in New Zealand, there would be little difference between the two possible methods.

The financial calculations are based on the number of animals required during gorse redevelopment, the cost and returns associated with the animals, the specific cost of chemicals and their application, and electric fencing for goats. The required goats and sheep are purchased and included as capital expenses within the budget. A farmer may supply the necessary sheep from the sheep on the farm in which case the associated capital cost is an opportunity cost. Animals are purchased in the year prior to requirement unless they are only required for grazing during part of the year. In this case they are purchased during the year not requiring a full 12 month grazing period. All costs and returns used in the analysis correspond to those used in the gross margins listed in Appendix 2 to 6.
CHAPTER 5

EXPERIMENTATION

5.1 Introduction

The economics of the two methods of gorse control were determined in both short-term and long-term analyses. The short-term economic implications are reported in the first section of this chapter and the long-term results in the last section.

Economic assessments and comparisons were mainly based on NPV results since this economic indicator is generally accepted as being the most appropriate in this type of study (Dasgupta and Pearce, 1972). Other economic measurements were used where applicable.

The available data allowed goat grazing rates between 6 and 18 goats per hectare to be assessed. Actual optimum goat grazing rates for gorse control could lie on either side of this range. Therefore, the estimated optimum goat grazing rates reported in this chapter should be viewed in relation to this restricted grazing range.

5.2 The Short-Term Assessment

The short term was defined as the current situation, with present technology, costs and returns. Some product prices and input costs were varied to assess the sensitivities of the short term.

5.2.1 Goat/sheep method.

The four goat enterprise options outlined in section 3.3.3 were compared. Briefly these options were:

OPTION 1: feral goats with income from cashmere,

OPTION 2: first and second cross wether goats with income from cashgora,

OPTION 3: feral does with income from progeny sold for meat,

OPTION 4: feral does crossed to angora bucks with doe kids sold as first cross and wether kids for scrub control.

These four goat options were compared within the gorse control program with the results shown in Figure 23. Each option was assessed under the range of goat grazing rates available for testing within the model. Under all goat grazing rates the ranking of the options was similar. Option 4 was economically the most viable option, with the
FIGURE 23: COMPARISON OF GOAT ENTERPRISE OPTIONS FOR GORSE CONTROL GIVEN CURRENT PRICES

The graph compares the Net Present Value (NPV) of various goat enterprise options at different initial goat densities per hectare. The options are labeled as follows:

- OPTION 1
- OPTION 2
- OPTION 3
- OPTION 4

The NPV is measured in $/ha at a 5% discount rate. The x-axis represents the initial goats per hectare ranging from 6 to 18.
best NPV per hectare being $3,873.8 Option 1 and option 2 were similar, with option 1 being slightly preferred. Option 3 was the least economic of the four options assessed. These results showed profit relativities between the options similar to those indicated by the gross margins in Appendices 2 to 5.

The insensitivity of the rate of gorse control to the particular range of goat grazing pressures assessed means that economic considerations are likely to determine the optimum goat grazing rates. Since the sale of first cross kid does is so lucrative, option 4 was most economic when using 18 goats per hectare. By comparison, all other goat enterprises tested were less profitable than the sheep enterprise, and so the economic analysis favours the 6 goats per hectare grazing rate. The relative profitability of sheep is reflected in the slopes of the observed responses in Figure 23. A positive slope indicates that the goat enterprise was more profitable than sheep (goat option 4) and a negative slope indicates a goat enterprise that was relatively less profitable than sheep (goat options 1, 2 and 3). Since option 4 was more profitable than the sheep enterprise, this option had a greater sensitivity to goat grazing rates.

The IRR values generated from the best goat grazing rates of each option are listed in Table 5. This criterion ranked options 2 and 3 differently to NPV, because option 2 required greater initial capital input. Compared with NPV, the IRR measurement gave a relatively higher ranking to projects which 'bunch' benefits into the early part of their economic lives (Dasgupta and Pearce, 1972); however, the IRR values still indicated goats as being a profitable means of controlling gorse with option 4 being the most profitable.

<table>
<thead>
<tr>
<th>Option</th>
<th>Goats per Hectare</th>
<th>IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>31.5</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>25.7</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>27.4</td>
</tr>
<tr>
<td>4</td>
<td>18</td>
<td>79.7</td>
</tr>
</tbody>
</table>

All NPV values were calculated with a discount rate of 5 per cent.
The projected development budget results for each goat option for both 6 and 18 goats per hectare stocking rates are presented in Appendices 10 to 13.

Inspection of these cash flows projected by the model indicated that options 1, 2 and 3 each broke even in year four, while option 4 reached the break-even point in year 2. The highest initial capital requirement occurred with option 2 at $590 per hectare. This was due to the relatively high cost of first and second cross wethers. Option 4 required initial capital of $470 per hectare while options 1 and 3 required the lowest at approximately $430 per hectare. Option 4 was the most favourable alternative since it generated a relatively high income from a relatively low capital input.

The clover benefit allowed for in relation to goat grazing, and reflected in improved sheep production, had little effect on determining optimum goat grazing rates. This is seen by the approximate linear relationship for each goat option in Figure 23. If significant, the benefit from clover would have been evident for treatments in the 6 to 12 goats per hectare range. (Due to data limitations, goat grazing rates above 12 goats per hectare were assumed to obtain the same economic benefit).

5.2.2 Chemical method.

In assessing the chemical method of gorse control, four different rates of development were assessed. These rates were based mainly on advisors' expectations (see Table 4, section 4.6) but also included a slower rate of development to provide for a pessimistic estimate. The rates of development using chemicals are given in Table 6 and indicate the rate at which full grazing potential was reached. Variations in the rate of development are a reflection in the management skills of the farmer.

<table>
<thead>
<tr>
<th>Year</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick Rate Development</td>
<td>0.6</td>
<td>0.85</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium (1) Rate Development</td>
<td>0.33</td>
<td>0.66</td>
<td>0.77</td>
<td>0.89</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium (2) Rate Development</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slow Rate Development</td>
<td>0.3</td>
<td>0.4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>0.9</td>
<td>1.0</td>
</tr>
</tbody>
</table>

9. Initial capital requirements are assumed to include additional livestock, fencing and burning and topdressing costs.
Figure 24 indicates the NPV results from these four rates of development. As expected, the quicker the return to full potential grazing, the better the economic result. The quick rate development was the most profitable, followed by the medium rates of development and then the slow rate development. Since a greater proportion of pasture carrying potential was reached in the first year, medium (2) rate was slightly more economical than medium (1) rate of development. Even though the economic ranking of the rates of development was expected, the result reflected the system's relative insensitivity to the various rates of development. The NPV per hectare value only improved by 16 per cent as chemical gorse control altered from the slow to the quick rate of development.

The IRR results for the various rates of development are given in Table 7. The IRR values gave the same economic ranking as NPV and indicate that all rates of development were economical.

Simulation results for the different rates of development for the chemical option are presented in Appendices 14 to 17. The quick development rate broke even in year 6 while for all other rates of development the break-even point was beyond the period of the development budgets (the chemical development budgets range from 6 to 8 years). By extrapolating the cash flows, it would appear that for both medium rate development strategies the break-even point occurred in year 7, while for the slow rate development it occurred in year 9. The initial capital required for the chemical option varied from $349 to $419 per hectare. This result was largely dependent on the potential grazing in the first year, since sheep purchase was also included in this figure.

TABLE 7

<table>
<thead>
<tr>
<th>Rate of Development</th>
<th>IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick</td>
<td>20.2</td>
</tr>
<tr>
<td>Medium (1)</td>
<td>18.4</td>
</tr>
<tr>
<td>Medium (2)</td>
<td>19.3</td>
</tr>
<tr>
<td>Slow</td>
<td>16.1</td>
</tr>
</tbody>
</table>

5.2.3 Comparison of goat/sheep and chemical methods.

A comparison of the four goat options and two of the chemical development strategies is shown in Figure 25. Estimated NPV ($/ha) indicate that while both were profitable, the goat/sheep options were more profitable than the chemical methods. The NPV difference between the most favourable chemical development rate and the least favourable
FIGURE 24: COMPARISONS OF THE DIFFERENT RATES OF DEVELOPMENT FOR CHEMICAL GORSE CONTROL GIVEN CURRENT PRICES
FIGURE 25: COMPARISON OF BOTH GOAT/SHEEP AND CHEMICAL METHODS OF GORSE CONTROL GIVEN CURRENT PRICES

GOAT OPTION 1

GOAT OPTION 2

GOAT OPTION 3

GOAT OPTION 4

CHEMICAL QUICK RATE DEVELOPMENT

CHEMICAL MEDIUM (1) DEVELOPMENT

NPV @ 5% ($/ha)
goat option was $270 per hectare in favour of the goat option. Thus, given current prices and technology, the goat/sheep method offers a more economical solution for gorse control.

This result was also reflected in the IRR results shown in Tables 5 and 7. All goat options gained higher IRR values than the most favourable chemical treatment.

Comparing the break-even point for the various gorse control methods, the goat/sheep methods achieved the break-even point the quickest. The longest goat/sheep break-even period was four years, while the shortest chemical break-even period was six years.

Initial capital requirements for the goat options range between $430 to $590 per hectare. This was higher than the chemical options which range between $349 to $419 per hectare. However, an important aspect of the goat options was that the capital investment in goats was regained once the goats are sold at the completion of gorse control. The chemical method, on the other hand, required capital to be 'sunken' into chemicals and chemical application. The chemical method also required additional capital to be invested during the development program due to follow-up chemical applications.

5.2.4 The sensitivity of results.

The results reported above indicate conclusively that the goat/sheep method is more economic than the chemical method in the short term. Sensitivity analysis therefore concentrated on assessing the circumstances that might cause the least profitable goat/sheep option to be less economic than the best rates of development of the chemical method in the short term. The sensitivities of the goat option 3 and the quick and medium (1) rate of chemical development were assessed in the sensitivity analysis. The quick and medium (1) rates of chemical development were used because they best represented the rates of chemical development obtainable by most farmers.

(1) The Price of 2,4,5-T.

Figure 26 indicates the effect on NPV ($/ha) given fluctuations in the price of 2,4,5-T. The lowest NPV ($/ha) value for the goat option (Option 3) was $2,090 and is marked by the dashed line in Figure 26. From Figure 26 it can be seen that the price of 2,4,5-T to the farm would have to decrease to within the range of -$6 to -$16 per litre for the chemical method to be as profitable as the least profitable goat option. In other words a decrease to this level would require substantial government subsidies, which are unlikely, given that chemical subsidies for weed control have recently been stopped. Therefore, it can be concluded that price variations in 2,4,5-T will not alter the conclusion that the goat/sheep method is the more profitable gorse control method, given that goat and sheep markets remain stable at current levels.
FIGURE 26: EFFECT OF CHANGING CHEMICAL PRICE ON THE PROFITABILITY OF THE CHEMICAL METHOD

NPV @ 5% ($/ha)

LOWEST GOAT OPTION NPV VALUE

QUICK RATE DEVELOPMENT

MEDIUM (1) RATE DEVELOPMENT

PRICE OF 2,4,5-T ($/1)
(2) The Price for Feral Goats

If goats became a popular method for gorse control and the supply was limited, the price of feral goats would increase. A range of feral goat prices was tested to see whether the relative profitability of the two gorse control methods would alter, and if the optimal goat stocking rates would change. Results for various feral goat prices using goat option 3 are given in Figure 27. These results were obtained by assuming that the price of the feral goat progeny would be the same as the feral goats. That is, as the prices for feral goats increased due to scrub control requirements, the progeny being equally valuable in scrub control would be priced at the same level.

The results indicated that the higher the price of feral goats the greater the profitability. This occurred because the increased value of the progeny more than offset the increase in initial capital outlay.

As the price of feral goats and kids increase, the relative profitability from the two extreme goat stocking rates tested (6 and 18 goats per hectare) converge. At an approximate price of $23 per head for feral goats and kids, the relative profitability of the two extreme goat stocking rates are equivalent (see Figure 27). At this point the return to the goat enterprise was similar to the sheep and there would be no financial difference in altering the proportions of goat and sheep in the gorse control grazing management. As prices for feral goats and kids go beyond $23 per head, the returns to goats are higher than current sheep returns and the most profitable stocking rate moves to 18 goats per hectare.

If prices for feral goats were to be zero, then the goat/sheep method is still more profitable than the most favourable chemical option. Thus, it would appear that variations in feral goat prices will not change the relative profitability of the goat/sheep or chemical methods.

(3) The Price for Kid Meat.

Variations in the price of kid meat may also affect the profit relativity between the two gorse control methods. Figure 28 shows the results of altering the price of kid meat in the model.

As expected, the profitability of the goat enterprise improved when the price of kid meat increased. At a price of $23 per kid there was little economic difference between the extreme goat grazing rates assessed (6 and 18 goats per hectare).

If the price for kid meat was to fall to zero, resulting in no income from the goat enterprise, the goat/sheep method would still be more economical than the chemical method. This again illustrated the definite economic advantages the goat/sheep method has in controlling gorse.
FIGURE 27: EFFECT ON THE PROFITABILITY OF THE GOAT/SHEEP METHOD GIVEN DIFFERENT FERAL GOAT PRICES

PRICE OF FERAL GOATS ($/hd)

NPV @ 5% ($/ha)

Current Price

6 goats/ha

18 goats/ha
FIGURE 28: EFFECT ON THE PROFITABILITY OF THE GOAT/SHEEP METHOD GIVEN DIFFERENT PRICES RECEIVED FOR KID MEAT

PRICES RECEIVED FOR KID MEAT ($/hd)
5.3 The Long-Term Assessment

To investigate the long-term economic implications of gorse control it was assumed that the goat product market would return to the levels indicated by goat option 3. This assumption was based on the current demand for angora goats being satisfied in the long term, thus decreasing the feral goat enterprise options to selling progeny for meat. Long-term cashmere and cashgora enterprises may return higher incomes than a kid meat enterprise but this was difficult to determine. It was also assumed that the quick and medium (1) term chemical development rates reflect the long-term chemical gorse control method. Given these assumptions both methods were assessed under changing returns to the sheep enterprise. The sensitivities of improved technology in the chemical method were also assessed.

5.3.1 Goat/sheep method.

The prices for wool and lambs were varied to simulate a change in sheep returns. The consequent effects on the economics of gorse control by the goat/sheep method are shown in Figure 29.

As expected, the decline in sheep returns decreased the profitability of the goat/sheep method. The system appeared sensitive to declining sheep returns with a 30 per cent decrease in sheep returns resulting in an approximate 50 per cent decline in NPV ($/ha). At a 50 per cent decline in sheep return, the NPV ($/ha) was below $500; however, at this level, the control of gorse was still profitable.

Over the range of sheep returns 6 goats per hectare still gave the better economic result than the 18 goats per hectare stocking rate. Thus 6 goats per hectare would appear to be the optimum goat stocking rate for the long-term scenario, given the range of goat stocking rates assessed.

5.3.2 Chemical method.

Similarly, the sheep returns were changed to assess the effects of the chemical method on gorse control. The results are given in Figure 30. Profitability of the chemical method was quite sensitive to variations in sheep product prices. A 30 per cent decrease in sheep returns resulted in a 60 per cent decrease in NPV ($/ha). The decreasing of sheep returns had a significant effect on the NPV and at a 50 per cent decrease, it was no longer profitable to clear gorse using the chemical method.

The quick rate of development remained the better chemical option, when compared with the medium (1) rate, but the two converged as the decline in sheep return increased.
FIGURE 29: EFFECT OF CHANGING SHEEP RETURNS ON THE GOAT/SHEEP METHOD OF GORSE CONTROL
FIGURE 30: EFFECT OF CHANGING SHEEP RETURNS ON THE CHEMICAL METHOD OF GORSE CONTROL

NPV @ 5%  ($/ha)

Quick Rate Development

Medium (1) Rate Development

PERCENTAGE CHANGE FROM CURRENT SHEEP RETURNS
5.3.3 **Comparison of the two methods of gorse control.**

Figure 31 indicates the NPV results for the best options of both gorse control methods under the declining sheep return situation with goat returns held constant. If current sheep return was to decrease by 50 per cent, the chemical method would no longer be profitable to control gorse. At this stage the goat/sheep method would be the only viable option. This result indicated that the chemical method is more sensitive to varying sheep returns than the goat/sheep method.

Since the chemical method gains all income from the sheep enterprise, and has the potential of obtaining full sheep production off the gorse infested area quicker than the goat/sheep method, the higher the sheep return the relatively more profitable the chemical method becomes. If sheep returns were to increase by 68 per cent (and goat returns were unchanged) both methods of gorse control would be equally profitable. Therefore in the long term the goat/sheep method will remain more profitable if relative sheep returns do not exceed an increase of 68 per cent on current sheep returns and current goat returns remain unchanged. In current terms a 68 per cent increase in sheep return represents a wool price of $4.82 per kg and an average lamb price of $24.81 per head.

5.3.4. **Technological advancement in the chemical method.**

Technological advancement in the chemical control of gorse could occur in the long term. Given the assumption that technological advancement may result in a decrease in chemical and application costs, the model was used to assess the likely long term effects. Figure 32 shows the results.

Chemical and application costs would need to decrease a substantial amount for the chemical method to become more profitable than the goat/sheep method. Given the most favourable chemical development rate, an 88 per cent decrease in chemical and application costs is required before chemical control becomes equivalent to the goat/sheep method. Therefore, in the long term, very substantial technological advancement would be required if the chemical method was to become the most economic option; such technological advancement appears unlikely.
FIGURE 31: COMPARISON OF THE GOAT/SHEEP AND CHEMICAL METHODS OF GORSE CONTROL GIVEN VARYING SHEEP RETURNS

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Quick Rate Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>2000</td>
<td>2000</td>
</tr>
<tr>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>4000</td>
<td>4000</td>
</tr>
</tbody>
</table>

NPV @ 5% ($/ha)

GOAT OPTION 3
6 Goats Per Hectare

PERCENTAGE CHANGE IN CURRENT SHEEP RETURNS
FIGURE 32: EFFECT OF DECREASING THE CHEMICAL AND APPLICATION COSTS ON THE CHEMICAL METHOD OF GORSE CONTROL

Quick Rate Development
Goat/Sheep Method
Long Term NPV Value
Medium (1) Rate Development

PERCENTAGE DECREASE IN CURRENT CHEMICAL APPLICATION COSTS

NPV @ 5% ($/ha)

2100
2000
1900
1800
1700
1600
0

-100 -80 -60 -40 -20

2000
1900
1800
1700
1600
0

-100 -80 -60 -40 -20
6.1 Introduction

The results presented in Chapter 5 indicate the relative profitability of the goat/sheep method of controlling gorse infested hill country compared with the chemical method. In this chapter the major implications of the results are discussed, with suggestions for further avenues of research.

6.2 Implications of the Results

6.2.1 General conclusion.

Given current prices and levels of technology, the goat/sheep method is a viable alternative to the chemical method of gorse control. Although both methods are profitable in controlling gorse, the goat/sheep method currently has the greater income potential and requires less lost capital input during the development program.

The goat/sheep method is more profitable for two main reasons. Firstly, the capital input is not lost since the goats can be sold once gorse control has been achieved. Obviously the chemical and application costs in the chemical method can not be recouped except in terms of consequent land productivity. Secondly, goat enterprises generate income during the process of gorse control. The amount of income is dependent on the particular goat enterprise, with at least one enterprise (goat option 4) currently receiving higher returns than commercial sheep enterprises. However, the analysis in Chapter 5 showed that even if no income was generated from goats, this method would still remain the most attractive alternative.

6.2.2 Potential goat returns in gorse control.

The current New Zealand markets for cashmere, cashgora, mohair and angora are experiencing rapid change. The present shortage of angora goats is sustaining a buoyant market for first cross goats. This market currently offers favourable returns when feral does used in gorse control are crossed with angora bucks. Also, the production of cashmere and cashgora from goats involved in gorse control is more profitable than the sale of progeny exclusively for meat. However, due to the infancy of these goat fibre markets in New Zealand, more producer and marketing experience is required before any long-term confidence can be placed in their viability. Although fibre markets may be uncertain, results from the model have demonstrated that the relative profitability
of the goat/sheep method compared to the chemical method is not sensitive to changes in goat product markets. Therefore, farmers can experiment with these enterprises assured of viability relative to the chemical method.

6.2.3 The trend in using goats for gorse control.

Traditionally, farmers have not used goats in gorse control despite the fact that it has been known for many years that this was possible (Wright, 1927). Some reasons for this became apparent during the course of this study. A goat enterprise adds to the complexity of management on a livestock farm. Farmers appear to have viewed the economic benefit of using goats as inadequate to stimulate a widespread move into this type of gorse control; however, with recent increases in the cost of chemical gorse control, and the advent of alternative goat enterprises, interest in using goats for scrub and gorse control has increased. The demand for goats for scrub control in the South Island is expected to prevent any kid meat being exported in 1984 (Moorhouse, 1983, pers. comm.). The improvements in goat product markets, combined with recent research at Ballantrae (D.S.I.R.) and Loburn (M.A.F.), have encouraged the current interest in gorse control by goats.

6.2.4 Economic sensitivity of gorse control systems.

(1) Chemical Rate of Development.

Even though the quickest rate of development to full pasture production was the most profitable, the rate of development for the chemical method had relatively little effect on the final economic outcome. Chemical and application costs, however, had a stronger influence on profitability. Any effort to improve the efficiency of the chemical method should, therefore, be directed towards decreasing costs rather than shortening the term of development. However, any further effort into improving the chemical method should be seriously questioned, since large decreases in chemical and application costs (greater than 85 per cent) are required for this method to be economically equivalent to the goat/sheep method.

(2) Price of 2,4,5-T.

Similarly, adjusting the current price of 2,4,5-T would have little effect on the relative profitability of the two gorse control methods. Even if 2,4,5-T was free, the goat/sheep method would still be the more economically favourable gorse control method.

(3) Sheep Returns

The factor to which the long-run profitability of gorse control is most sensitive is sheep production prices. As sheep returns increase, there is greater economic benefit in quickly reaching full grazing
potential. Gorse control by chemicals provides the potential to achieve full grazing potential quickly. Therefore, as sheep production prices improve, the relative profitability of the chemical method increases. In the long run it was assumed that the goat/sheep method’s profitability would be equivalent to the current enterprise selling kid meat. If this is the case, then the chemical method would become more profitable than the goat/sheep method if sheep product prices increased by more than 68 per cent relative to other current costs and returns. Given current prices, this represents a price for wool of $4.80 per kg and an average price for lambs of $24.80 per head.

Similarly, if the returns to sheep decrease, the chemical method would be affected more than the goat/sheep method. If current sheep product prices fell by 50 per cent, and other costs and returns remained constant, it would not be profitable to control gorse by chemicals, thus leaving the goat/sheep method as the only viable alternative. The goat/sheep method would remain viable, however, only until sheep returns fell below 64 per cent of levels.

(4) Improved Technology in the Chemical Method.

If improved techniques of chemical control can be represented by decreasing chemical and application prices, then a large technical improvement is required for the relative profitabilities to alter. For example, a decrease of 85 per cent in the costs of the chemical method would only allow the best chemical control term development to break even with the long-run goat/sheep alternative. The relative profitability of the chemical method would therefore appear to be insensitive to likely improvements in technology.

6.2.5 Clover benefit due to goat grazing.

Clover content in the pasture increases when the pasture is predominantly grazed by goats. This increased level of clover was considered to determine whether it would result in increased sheep production. Due to the lack of data and information relating clover content in the pasture with sheep production, ewe live weights recorded in the Ballantrae trial were the only indication of increased clover benefit. The maximum clover benefit obtained through estimates using ewe live weights was $1.80 per S.U. at current wool and lamb prices. The insensitive financial response of this model to the clover benefit can be related to three factors: firstly, the clover benefit was only available at higher goat grazing proportions and conversely, was thus only available to a low proportion of sheep; secondly, the clover benefit only occurred during two of the five years of the development budget, so only a short period benefitted financially from clover; finally, the maximum financial reward per S.U. from improved clover was a relatively small increase in sheep returns (12 per cent increase in the sheep gross margin per S.U.).
The clover benefit may have been underestimated; however, due to the sensitivities of the system as modelled, an improved estimate of the clover benefit would not have altered the profit relativities between the two methods of gorse control.

6.3 Extension of the Model

Borrowing finance and tax assessment were not included in this analysis. These aspects affect each farmer differently and so were left for assessment during actual decision making. The model developed for this analysis, and described in detail by Krause (1983), provides a detailed development budget describing the cash flows, which could help decision makers assess the effects of tax and borrowed finance if required.

The model was designed to be operated interactively and to allow most economic and some physical variables to be easily altered. This aids experimentation and would permit the model to be useful in any future analysis when current situations have changed.

6.4 Scope for Future Research

The insensitivity of the model’s results to changing economic parameters (Chapter 5) clearly illustrates the economic advantages of the goat/sheep method over the chemical method of gorse control. Given current prices, the best goat/sheep option is twice as profitable as the best chemical rate of development. Obviously any further research in gorse control should be directed towards the goat/sheep method.

6.4.1 Management research.

Current research at Ballantrae and Loburn was undertaken to determine whether goats could control gorse. While the trials differed slightly in their approach to the problem, both proved the effectiveness of goats in controlling gorse. The improvement of goat management for gorse control would thus appear to be the most worthwhile area for the next phase of research.

The major result from the model with management implications was that the lowest stocking rate assessed (6 goats per hectare) for gorse control was generally preferred. This indicates that the optimum goat grazing rate could well be below the range assessed. Goat management strategies could improve then, if the minimum goat grazing requirements for adequate gorse control were known. Further research is thus required to assess lower stocking rates (below 6 goats per hectare) to help determine the minimum goat grazing requirements.

The Ballantrae trial commenced with a low density of gorse and the goat grazing treatments (6, 12 and 18 goats per hectare) showed little difference with respect to the time required to control gorse. This result, together with results from model experimentation, indicates that, at low gorse densities, a low rate of goat grazing is sufficient
for efficient gorse control. The Loburn trial, however, began with a higher rate of gorse density and in this trial it appears that gorse control was more sensitive to stocking pressure than at Ballantrae (see Figure 2.3). At Loburn, not all treatments began with the same density of gorse and only two goat grazing pressures were involved (10 and 20 goats per hectare) thus no strict comparisons can be made between the Loburn and the Ballantrae trials. The results from this limited data presently available, however, indicate that goat stocking rates required for effective gorse control may be related to the initial density of gorse. More research is required to determine the relationship between gorse control with different goat grazing rates and different initial densities of gorse. The emphasis needs to be on determining the minimum grazing rates required for different gorse densities.

6.4.2 Clover content and sheep production.

A method has been devised to simulate competitive and complementary grazing between goats and sheep (see Krause, 1983); however, due to the lack of data related to the relationship between clover production levels and sheep production, this method could not be utilised in this study. This lack of information should receive some priority in further research. Not only would it assist a simulation approach to studying complementary grazing between goats and sheep, but it would also help to clarify the specific value of clover in the New Zealand grazing systems. In particular, research is required to assess sheep production (i.e. lambing percentage and wool production) expected from adequately producing pastures with varying proportions of clover on offer at different times of the year.

6.4.3 Goat gorse grazing research.

This study highlights three specific factors that should be explored in future research into the control of gorse by goats:

(a) The basic underlying assumption of the model used in this study was that the rate of gorse control is solely dependent on the goat grazing pressure. This assumption appears sound since in both the Ballantrae and Loburn trials, the higher the goat grazing rate, the quicker the decline in gorse height in the first year (see Figure 2.3). Clarke et al (1982) also found that unlike sheep, goats actively select gorse in preference to clover and grass. Thus, goats have a greater ability to control gorse than sheep. It would seem logical, therefore, that future research into gorse control should be aimed at exploring the effect of goat grazing pressure per se rather than sheep/goat ratios. A possible procedure would be:

(i) when increased grazing rates were required to utilize increased pasture growth, only sheep grazing pressure should be increased,
(ii) goat grazing rates need only increase if gorse growth is uncontrolled.

This approach to gorse grazing research and management is economically justifiable, as most of the pasture would be utilized by the more profitable sheep enterprise.

(b) The objective of gorse control is to decrease effective gorse cover to zero and then maintain control at that level. Goat stocking rates should vary accordingly. A higher stocking rate is necessary while gorse is being controlled but then a lower maintenance stocking rate is likely to be sufficient to retain gorse at zero effective pasture cover. Such stocking rate strategies have not yet been explored in goat gorse grazing trials. Both the Ballantrae and Loburn trials maintained stocking proportions in each treatment beyond zero effective gorse cover. Hence, no research data are available on the maintenance goat grazing pressure. Future research should incorporate this variable approach to goat stocking management since it more closely reflects the on-farm situation.

(c) The decline of effective gorse cover needs to be carefully monitored, preferably at quarterly time intervals throughout a trial. This will facilitate the ease of interpreting and analysing results. Although a strong linear relationship between gorse height and gorse cover was estimated from Loburn data, which helped to extrapolate effective gorse cover, a more direct measure of effective gorse cover would be useful and the collection of such data is recommended in future research.

6.4.4 Gorse as a resource.

As seen by the goat enterprise options assessed in this study, feral goats do provide the potential to earn income. Under present conditions one of these options (option 4) has become economically competitive to sheep returns. In this situation, gorse could be viewed as a feed source rather than a weed, thus altering the management objective to one of managing gorse as a resource for the goat enterprise. This option opens up a large area for research including feed requirements of goats, the quality of gorse as a goat feed and the best grazing management for the ideal utilization of gorse. This concept of viewing gorse as a resource rather than a weed presents interesting prospects for hill country farming. This could be an important area for future research after the basic investigations on gorse control have been completed.
REFERENCES


Batten, G.J. (1979a) "Controlling Scrubweeds with Goats", New Zealand Journal of Agriculture, 139(4):31-32


Batten, G.J. (1979c) "Goats: Management", AGLINK FPP281, Ministry of Agriculture and Fisheries, Wellington.


MacLean, S.M. (1956), "Weedkillers as an Aid to the Establishment, Maintenance and Renovation of Pastures", Proceedings 9th New Zealand Weed Control Conference, pp.94-100.


Rennie, N. (1979) "Gorse Seedlings Eaten by Demonstration Farm Stock", The New Zealand Farmer, 100(7):20-21


LIST OF PERSONAL COMMUNICATIONS


McGregor, M. (1983), Lecturer, Lincoln College.


Pottinger, G. (1983), Lecturer, Lincoln College.


Thompson, K. (1983), Lecturer, Lincoln College.


APPENDIX 1

THE GORSE CHEMICAL SPRAY PROGRAM

This recommendation is given by the Ministry of Agriculture and Fisheries (Anon, 1982b).

Recommendations for developing country from gorse are, in the light of the Te Moana Nui experience:

1. Pre-burn spray, October-November, with 2,4,5-T (72% active ingredient, i.e., double strength) at 5 litres/ha (half label rate).

2. Burn late March-early April (later than was usual in the district).

3. Fly on seed mix (20kg Ruanui, 4kg white clover, 2kg sub clover on sunny faces) and 600kg of super immediately after burn.

4. Subdivide tightly enough to enable grazing pressure of at least 250 ewes/ha.

5. Lightly stock over first winter.

6. Rotationally mob-graze ewes and lambs in October to trim off spring growth. Leave enough sheep in to check growth until helicopter spraying.

7. Blanket-spray at low volume when gorse seedlings are about 4cm long. This is usually mid-October, about six months after the autumn burn. 2,4,5-T (double strength again) at 1.5 litres/ha in 50 litres of water will kill most seedlings and knock stump regrowth without killing newly established clovers.

8. Wean in first week of December and rotationally graze ewes at not less than 250/ha over December-January.

9. Graze normally within whole-farm program for the rest of the year.

10. Repeat the mid-October grazing treatment (see 6 above).
11. Apply second **low-volume 2,4,5-T blanket spray** whether or not gorse seedlings are easily seen. If they are very small use 1 1/2 litres in 50 litres water. If plants have survived from previous year use 2 litres.

12. Repeat steps 8 to 12 for another year or more until there are only a few plants better dealt with by grubber or knapsack Micron blower.

"Other techniques will also be effective if adequate follow-up pressure is maintained but the above approach is effective, manageable and increases production in the shortest time with the least amount of chemical", (Fred Phillips, M.A.F. Advisor, Wanganui).
APPENDIX 2

FERAL GOAT GROSS MARGIN: CASHMERE PRODUCTION

This example is for a dry feral doe and wether flock used in gorse control with the potential for cashmere production. Replacements are bought every year to allow stocking rates to be maintained. This gross margin estimate has been compiled with the aid of Moorhouse (1983, pers. comm.), Parkinson (1983, pers. comm.), Squire-Wilson (1983, pers. comm.) and Woodward (1983, pers. comm.). The gross margin is based on a 500 goat herd.

Cashmere Production Estimates

This market is relatively new to New Zealand and expected production from feral goats is still being ascertained. Hence a range of cashmere production at an average price was used to obtain the following cashmere production estimates. Parkinson (1983, pers. comm.) suggested that $15 gross per feral could be expected from cashmere production. This figure may be high since goats selected for gorse control may not be subject to the level of selection pressure suggested by Parkinson (1983, pers. comm.) (approximately 1 goat selected in 20). Production of a 200 gm fleece @ 50% yield @ $110/kg was assumed in this gross margin giving a gross return of $11.00/head; however, a lower level of production involving a 100 gm fleece @ 30% yield giving a gross return of $3.30/head is conceivable.

Production Parameters Assumed

10% death rate, 200 gm fleece @ 50% yield
Gross Margin

Gross Revenue

500 goats @ $11.00/head cashmere

\[ \text{TOTAL GROSS REVENUE} \]
\[ 5500.00 \]

Variable Costs

Goat health $1.44/head (based on equivalent ewe health costs listed in Appendix 6)

\[ 720.00 \]

2 x shearings @ $1.05/head (based on ewe shearings and shed costs listed in Appendix 6)

\[ 1050.00 \]

Transport of cashmere to Australia $1/kg

\[ 100.00 \]

Transport for replacements @ $0.50/head

\[ 25.00 \]

Replacements 50 @ $13.00/head

\[ 650.00 \]

Interest on livestock capital (500 @ $13.00/head @ 14%)

\[ 910.00 \]

\[ \text{TOTAL VARIABLE COSTS} \]
\[ 3455.00 \]

\[ \text{TOTAL GROSS MARGIN} \]
\[ 2045.00 \]

Variable Cost per feral goat = $6.91

Gross Margin per feral goat = $4.09

Gross Margin per S.U. (1 goat = 0.5 S.U.) = $8.18
APPENDIX 3

FIRST AND SECOND CROSS ANGORA GOAT GROSS MARGIN: CASHGORA PRODUCTION

This example is for first and second cross wether angoras with the potential of producing cashgora C. At a death rate of 10%, replacements must be purchased yearly. This gross margin estimate has been compiled with the aid of Moorhouse (1983, pers. comm.) and Woodward (1983, pers. comm.). The gross margin is for a 500 goat herd.

Cashgora Production Estimates

It is assumed these animals are older than 12 months and thus suitable for gorse control. Their fibre is of cashgora C class currently priced at $14.25/kg. Each animal clips 1 kg per year.

Production Parameters Assumed

10% death rate, 1kg Cashgora C from one shearing per year.

Gross Margin

<table>
<thead>
<tr>
<th>Gross Revenue</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 goats @ 1kg/head @ $14.25/kg</td>
<td>7125.00</td>
</tr>
<tr>
<td>TOTAL GROSS REVENUE</td>
<td>7125.00</td>
</tr>
</tbody>
</table>
90.

Variable Costs

Goat health $1.44/head (based on equivalent ewe health costs listed in Appendix 6) 720.00
Shearing @ $1.05/head (based on ewe shearing and shed costs listed in Appendix 6) 525.00
Transport of cashgora to Australia @ $1/kg 500.00
Replacements 50 @ $40.00 2000.00
Transport for replacements @ $0.50/head 25.00
Interest on livestock capital (500 @ $40.00 @ 14%) 2800.00

TOTAL VARIABLE COSTS 6570.00
TOTAL GROSS MARGIN 555.00

Variable Cost per feral goat = $13.14
Gross Margin per feral goat = $1.11
Gross Margin per S.U. (1 goat = 0.5 S.U.) = $2.22
FERAL GOAT GROSS MARGIN: KID MEAT PRODUCTION

This example is for a feral doe herd with all surplus progeny sold for meat. This gross margin represents the traditional disposal of feral goat progeny and was compiled with the aid of Moorhouse (1983, pers. comm.). The gross margin example is based on a 500 feral doe herd.

Production Parameters Assumed

10% death rate; 2.5% bucks; 80% kidding; all surplus progeny sold for meat; self replacing doe herd.

Gross Margin

Gross Return

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kids 212 @ $7/head</td>
<td>$1484.00</td>
</tr>
<tr>
<td>TOTAL GROSS REVENUE</td>
<td>$1484.00</td>
</tr>
</tbody>
</table>

Variable Costs

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat health - does @ $1.44/head (based on equivalent ewe health costs listed in Appendix 6)</td>
<td>$720.00</td>
</tr>
<tr>
<td>- kids @ $0.33/head (based on equivalent lamb health costs listed in Appendix 6)</td>
<td>$132.00</td>
</tr>
<tr>
<td>Transport kids to works $0.50/head</td>
<td>$106.00</td>
</tr>
<tr>
<td>Interest on livestock capital (500 feral does @ $13.00/head @ 14%)</td>
<td>$910.00</td>
</tr>
<tr>
<td>TOTAL VARIABLE COSTS</td>
<td>$1868.00</td>
</tr>
<tr>
<td>TOTAL GROSS MARGIN</td>
<td>-$384.00</td>
</tr>
</tbody>
</table>

Variable Cost per doe = $3.74
Gross Margin per doe = -$0.77
Gross Margin per S.U. (1 feral doe = 0.5 S.U.) = -$1.54
APPENDIX 5

FERAL GOAT GROSS MARGIN: SELLING FIRST CROSS DOE KIDS FOR BREEDING AND WETHER KIDS FOR SCRUB CONTROL

This example is for feral does crossed to angora with all doe kids sold to angora breeders as first cross does and first cross wethers sold for scrub clearance. This gross margin was compiled with the aid of Moorhouse (1983, pers. comm.) and is based on a herd size of 500 feral does. Since first cross kid does are so valuable, replacement feral does are bought each year.

Production Parameters Assumed

10% death rate; 2.5% bucks; 80% kidding; all doe kids sold as first cross for breeding and wether kids for scrub control.

Gross Margin

<table>
<thead>
<tr>
<th>Gross Return</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doe kids, first cross 200 @ $80/head</td>
<td>16000.00</td>
</tr>
<tr>
<td>Wether kids, first cross 200 @ $13/head</td>
<td>2600.00</td>
</tr>
<tr>
<td><strong>TOTAL GROSS REVENUE</strong></td>
<td><strong>18600.00</strong></td>
</tr>
</tbody>
</table>
Variable Costs

Goat health - does @ $1.44/ head (based on equivalent ewe health costs listed in Appendix 6)
- kids @ $0.33/head (based on equivalent lamb health costs listed in Appendix 6)

Purchase replacement feral does
50 @ $13/head

Purchase of replacement angora bucks
3 @ $250/head

Transport for replacements @ $0.50/head

Interest on livestock capital
500 feral does @ $13.00/head @ 14%
12 angora bucks @ $250.00/head @ 14%

TOTAL VARIABLE COSTS 3609.00
TOTAL GROSS MARGIN 14991.00

Variable Cost per doe = $7.22
Gross Margin per doe = $29.98
Gross Margin per S.U. (1 feral doe = 0.5 S.U.) = $59.96
APPENDIX 6

SHEEP GROSS MARGIN

This example is based on the 1983 Farm Budget Manual (FINANCIAL, Vol. 2) sheep gross margin compiled by McGregor (1983, pers. comm.) and adjusted for the North Island hill country with aid fromPottinger (1983, pers. comm.).

This flock consists of 1000 ewes and 380 hoggets. Surplus ewe lambs and 50 per cent of the wether lambs are sold as store, while the remainder of wether lambs (50 per cent) are sold as prime for export.

Production Parameters Assumed

90% lambing; hogget replacement kept to cover 5% ewe culling; 20% two tooth culled; death rate of 4%; ewe wool clip is 4.50kg.

Gross Revenue

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb sales - 511 prime lambs @ $14.77</td>
<td>75</td>
<td>15.00</td>
<td>1125.00</td>
</tr>
<tr>
<td>(including skins and wool)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>239 ewes @ $7.00</td>
<td></td>
<td></td>
<td>1673.00</td>
</tr>
<tr>
<td>Hill sheep sales - 75 two tooth</td>
<td>239</td>
<td></td>
<td>12915.00</td>
</tr>
<tr>
<td>239 ewes @ $7.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wool Sales 4500 kg @ $2.87/kg net</td>
<td>9500</td>
<td></td>
<td>5998.30</td>
</tr>
<tr>
<td>(1000 ewes @ 4.5 kg allowing for deaths)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Wool price is gross less 33c/kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2900 kg @ $2.87/kg net</td>
<td></td>
<td></td>
<td>5998.30</td>
</tr>
<tr>
<td>(380 hoggets @ 5.5 kg allowing for deaths)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>29258.77</td>
</tr>
</tbody>
</table>

TOTAL GROSS REVENUE

29258.77
Variable Costs

Shearing - 1000 sheep @ $75/100
   - 380 hoggets @ $75/100
   $750.00

Tup crutch - 990 ewes @ $23/100
   $227.70

Main crutch - 990 ewes @ $32/100
   $316.80

Drenching - 2 drenches @ 13c/dose for 1015 (ewes are drenched once before lambing)
   - lambs, 1850 doses @ 6.46c/dose
      replacements drenched 3 times, stores twice, and primes once)
   $263.90

Vaccination - triple vaccine, 980 ewes
   @ 14.57c/sheep
   - triple vaccine, 370 hoggets
     @ 14.57c/sheep
   $142.79

Eartags, footrot and docking
   $475.00

Dipping - 990 ewes @ 27c/head
   - 376 hoggets @ 27c/head
   - 660 lambs @ 27c/head
   $267.30

Woolshed expenses including wool packs,
   twine, glue, emery paper and shearing
   plant expenses, approximate costs @ 30c/ewe
   and 17c/hogget
   $364.00

Ram costs - 2 per 100, 4 year life
   5 @ $150/ram
   $750.00

Cartage - store lambs to yards 450 @ $1.00/head
   - cull two tooths and five year old to yards, 264 @ $1.57 each
   - cull ewes to works 50 @ $1.57 each
   - wool 5658 kg @ 4.8c/kg
   $414.48

Selling charges - yard fees 444 lambs
   @ 26c/lamb
   - commission $6726 @ 4.75%
   $319.49

Interest on livestock capital (1370 ewes
   @ $26/head @ 14%)
   $4986.80

TOTAL VARIABLE COSTS
   $10932.52

TOTAL GROSS MARGIN
   $18326.28
Variable Cost per ewe = $10.94
Gross Margin per ewe = $18.32
Gross Margin per S.U. (1 ewe = 1 S.U.) = $14.68
APPENDIX 7

TOPDRESSING COSTS

Topdressing is required for pasture establishment after the initial gorse stand is burnt. This topdressing is required for both goat/sheep and chemical methods of gorse control. The following quantities for topdressing came from Rennie (1979).

<table>
<thead>
<tr>
<th>Topdressing</th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superphosphate 500kg/ha @ $142/t (on farm)</td>
<td>71.00</td>
</tr>
<tr>
<td>Ruanui Ryegrass 25kg/ha @ $1.80/kg</td>
<td>45.00</td>
</tr>
<tr>
<td>Paroa Ryegrass 4kg/ha @ $2.40/kg</td>
<td>9.60</td>
</tr>
<tr>
<td>Huia White Clover 2kg/ha @ $4.50/kg</td>
<td>9.00</td>
</tr>
</tbody>
</table>

**TOTAL COST PER HA**

134.60

It is assumed spreading is by air from a fixed wing aircraft. The weight to be spread per hectare is 531 kg (approx. 0.5t). For the 30 ha example, the following topdressing cost will be used.

<table>
<thead>
<tr>
<th></th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds and fertiliser</td>
<td>4038.00</td>
</tr>
<tr>
<td>Spreading by Air: 531kg/ha @ 30 ha = 15.91 @ 12t/hr @ $417/hr</td>
<td>553.60</td>
</tr>
</tbody>
</table>

**Total topdressing costs for 30ha are**

4591.60
Goats require good fencing and electric fencing has proven adequate for this job. Below are the costings for erecting a one electric wire on an existing fence obtained from Warren (1983, pers. comm.). This example assumes electricity needs to be brought from a mains 1 kilometre away.

Illustration of Example used (30ha)
Costing of Material and Contract Labour

**Mains to Energiser (1 Km)**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energiser</td>
<td>250.00</td>
</tr>
<tr>
<td>Aluminium lead out wire</td>
<td>150.00</td>
</tr>
<tr>
<td>100 insulators</td>
<td>20.00</td>
</tr>
<tr>
<td>Earthing material for the energiser</td>
<td>50.00</td>
</tr>
<tr>
<td>Underground cables</td>
<td>30.00</td>
</tr>
<tr>
<td>Labour cost (including installing earth stakes and digging in underground cable)</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**TOTAL**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>600.00</td>
</tr>
</tbody>
</table>

**Fencing Costs for the 30 ha Paddock**

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>2200m of 2.5m high tensile wire @ $55.00/Km</td>
<td>121.00</td>
</tr>
<tr>
<td>275 stand of insulators @ $1.10/insulator (8m spacing)</td>
<td>303.00</td>
</tr>
<tr>
<td>Labour cost</td>
<td>120.00</td>
</tr>
</tbody>
</table>

**TOTAL**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>544.00</td>
</tr>
</tbody>
</table>

Total fencing costs for the 30 ha is $1144.00
The costings for chemical application to control gorse are based on the M.A.F. recommendation outlined in Appendix 1. Current costings are:

**Initial Blanket Spray**
- Spray 2,4,5-T @ $15.37/l @ 5 l/ha
- This spray is applied with 2201 of water per hectare at a helicopter cost of 76.85

**Lighter Blanket Spraying**
- Spray 2,4,5-T @ $15.37/l @ 1.5 l/ha
- This spray is applied with 55 l of water per hectare at a helicopter cost of 45.79

**Maintenance Spraying**
- Since gorse seeds have long dormancy periods a maintenance spot spray may be necessary to check regeneration of gorse once the initial stand is entirely checked. A cost of $2.00 per S.U. is currently assumed by many farmers as a likely maintenance spraying cost (Phillips, 1983, pers. comm.). At a potential carrying capacity of 9 S.U./ha this maintenance cost is $18/ha.
# Appendix 10

## Gorse Control Development Budgets Using Goat Option 1

**Goat Option 1** current prices, 6 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL DATA</strong>&lt;br&gt;no. of goats</td>
<td>(initial goats = 6.00/ha)</td>
<td>180.</td>
<td>180.</td>
<td>180.</td>
<td>60.</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td>0.0</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td>0.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
</tr>
<tr>
<td><strong>REVENUES</strong>&lt;br&gt;goats: fibre - cashmere ($110.00/kg)</td>
<td>0.</td>
<td>1980.</td>
<td>1980.</td>
<td>660.</td>
<td>660.</td>
</tr>
<tr>
<td>sheep: (wool $2.87/kg) (lambs $14.77/hd)</td>
<td>0.</td>
<td>3718.</td>
<td>3718.</td>
<td>4957.</td>
<td>4957.</td>
</tr>
<tr>
<td>goats: sales - feral (does &amp; wths.) ($13.00/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>1560.</td>
<td>0.</td>
</tr>
<tr>
<td><strong>TOTAL RETURN</strong></td>
<td>0.</td>
<td>5698.</td>
<td>5698.</td>
<td>7177.</td>
<td>5617.</td>
</tr>
<tr>
<td><strong>COSTS</strong> (no land included)&lt;br&gt;goats: purchase - feral does &amp; wths. ($13.00/hd)</td>
<td>2340.</td>
<td>234.</td>
<td>234.</td>
<td>78.</td>
<td>78.</td>
</tr>
<tr>
<td>sheep: purchases (ewes) ($26.00/hd)</td>
<td>4680.</td>
<td>0.</td>
<td>0.</td>
<td>1560.</td>
<td>0.</td>
</tr>
<tr>
<td>fencing: one hot wire</td>
<td>1144.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>burning</td>
<td>100.</td>
<td>4592.</td>
<td>4592.</td>
<td>4592.</td>
<td>4592.</td>
</tr>
<tr>
<td>goats: variable costs ($3.69/hd)</td>
<td>0.</td>
<td>664.</td>
<td>664.</td>
<td>221.</td>
<td>221.</td>
</tr>
<tr>
<td>sheep: variable costs ($4.87/hd)</td>
<td>0.</td>
<td>877.</td>
<td>877.</td>
<td>1169.</td>
<td>1169.</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td>12856.</td>
<td>1775.</td>
<td>1775.</td>
<td>3028.</td>
<td>1468.</td>
</tr>
<tr>
<td><strong>NET CASH FLOW</strong></td>
<td>-12856.</td>
<td>3923.</td>
<td>3923.</td>
<td>4149.</td>
<td>4149.</td>
</tr>
<tr>
<td><strong>CUMULATIVE CASH FLOW</strong></td>
<td>-12856.</td>
<td>-8933.</td>
<td>-5010.</td>
<td>-861.</td>
<td>3288.</td>
</tr>
</tbody>
</table>

**IRR = 29.90%**<br>**NPV at 5% = $68354.**<br>**Benefit Cost Ratio at 5% = 2.55**
**APPENDIX 10 (cont.)**

**GOAT OPTION 1: current prices, 18 goats per hectare**

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL DATA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of goats (initial goats = 18.00/ha)</td>
<td>540.</td>
<td>540.</td>
<td>540.</td>
<td>60.</td>
<td>60.</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>240.</td>
<td>240.</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td>0.0</td>
<td>4.50</td>
<td>4.84</td>
<td>4.67</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td>0.0</td>
<td>90.0</td>
<td>95.6</td>
<td>92.6</td>
<td>90.0</td>
</tr>
<tr>
<td><strong>RETurnS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: fibre - cashmere ($110.00/kg)</td>
<td>0.</td>
<td>5940.</td>
<td>5940.</td>
<td>660.</td>
<td>660.</td>
</tr>
<tr>
<td>sheep: (wool $ 2.87/kg) (lambs $ 14.77/hd)</td>
<td>0.</td>
<td>0.0</td>
<td>0.</td>
<td>5166.</td>
<td>4957.</td>
</tr>
<tr>
<td>goats: sales - feral (does &amp; wths.) ($ 13.00/ha)</td>
<td>0.</td>
<td>0.0</td>
<td>0.</td>
<td>6240.</td>
<td>0.</td>
</tr>
<tr>
<td><strong>TOTAL RETURN</strong></td>
<td>0.</td>
<td>5940.</td>
<td>5940.</td>
<td>12066.</td>
<td>5617.</td>
</tr>
<tr>
<td><strong>COSTS (no land included)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: purchase - feral does &amp; wths. ($ 13.00/ha)</td>
<td>7020.</td>
<td>702.</td>
<td>702.</td>
<td>78.</td>
<td>78.</td>
</tr>
<tr>
<td>sheep: purchases (ewes) ($ 26.00/ha)</td>
<td>0.</td>
<td>0.0</td>
<td>0.</td>
<td>6240.</td>
<td>0.</td>
</tr>
<tr>
<td>fencing: one hot wire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1144.</td>
</tr>
<tr>
<td>burning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.</td>
</tr>
<tr>
<td>topdressing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4592.</td>
</tr>
<tr>
<td>goats: variable costs ($ 3.69/ha)</td>
<td>0.</td>
<td>1993.</td>
<td>1993.</td>
<td>221.</td>
<td>221.</td>
</tr>
<tr>
<td>sheep: variable costs ($ 4.87/ha)</td>
<td>0.</td>
<td>0.0</td>
<td>0.</td>
<td>1169.</td>
<td>1169.</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td>12856.</td>
<td>2695.</td>
<td>2695.</td>
<td>7708.</td>
<td>1468.</td>
</tr>
<tr>
<td><strong>NET CASH FLOW</strong></td>
<td>-12856.</td>
<td>3245.</td>
<td>3245.</td>
<td>4358.</td>
<td>4149.</td>
</tr>
</tbody>
</table>

**IRR = 24.40%**  
**NPV at 5% = $ 63232.**  
**Benefit Cost Ratio at 5% = 2.27**
## APPENDIX 11

**GORSE CONTROL DEVELOPMENT BUDGETS USING GOAT OPTION 2**

**GOAT OPTION 2** current prices, 6 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>PHYSICAL DATA</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of goats</td>
<td>180.</td>
<td>180.</td>
<td>180.</td>
<td>60.</td>
<td>60.</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Returns</th>
<th>0.</th>
<th>6283.</th>
<th>6283.</th>
<th>10612.</th>
<th>5812.</th>
</tr>
</thead>
<tbody>
<tr>
<td>goats: fibre</td>
<td>0.</td>
<td>2565.</td>
<td>2565.</td>
<td>855.</td>
<td>855.</td>
</tr>
<tr>
<td>cashgora ($14.25/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep: wool</td>
<td>0.</td>
<td>3718.</td>
<td>3718.</td>
<td>4957.</td>
<td>4957.</td>
</tr>
<tr>
<td>($2.87/kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: sales</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>1st &amp; 2nd X wethers ($40.00/hd)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Costs (no land included)</th>
<th>0.</th>
<th>7200.</th>
<th>720.</th>
<th>720.</th>
<th>240.</th>
<th>240.</th>
</tr>
</thead>
<tbody>
<tr>
<td>goats: purchase</td>
<td>0.</td>
<td>1144.</td>
<td>100.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>1st &amp; 2nd X wethers ($40.00/hd)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep: purchase (ewes)</td>
<td>0.</td>
<td>4680.</td>
<td>1169.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>($26.00/hd)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>fencing</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>one hot wire</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>burning</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>topdressing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: variable costs</td>
<td>0.</td>
<td>0.</td>
<td>212.</td>
<td>212.</td>
<td>212.</td>
<td></td>
</tr>
<tr>
<td>($3.54/hd)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep: variable costs</td>
<td>0.</td>
<td>0.</td>
<td>1169.</td>
<td>1169.</td>
<td>1169.</td>
<td></td>
</tr>
<tr>
<td>($4.87/hd)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Total Costs</th>
<th>17716.</th>
<th>2234.</th>
<th>2234.</th>
<th>3181.</th>
<th>1621.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net Cash Flow</td>
<td>-17716.</td>
<td>4049.</td>
<td>4049.</td>
<td>7431.</td>
<td>4191.</td>
</tr>
</tbody>
</table>

**IRR** = 22.32%  **NPV at 5% = $64490.**  **Benefit Cost Ratio at 5%** = 2.23
APPENDIX 11 (cont.)

GOAT OPTION: current prices, 18 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICAL DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of goats (initial goats = 18.00/ha)</td>
<td>540</td>
<td>540</td>
<td>540</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td>0.0</td>
<td>4.50</td>
<td>4.84</td>
<td>4.67</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td>0.0</td>
<td>90.0</td>
<td>95.6</td>
<td>92.6</td>
<td>90.0</td>
</tr>
<tr>
<td>RETURNS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: fibre - cashgora ($ 14.25/kg)</td>
<td>0.</td>
<td>7695</td>
<td>7695</td>
<td>855</td>
<td>855</td>
</tr>
<tr>
<td>sheep: (wool $ 2.87/kg) (lambs $ 14.77/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>5166</td>
<td>4957</td>
</tr>
<tr>
<td>goats: sales - 1st &amp; 2nd X wethers ($ 40.00/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>19200</td>
<td>240</td>
</tr>
<tr>
<td>TOTAL RETURN</td>
<td>0.</td>
<td>7695</td>
<td>7695</td>
<td>25221</td>
<td>5812</td>
</tr>
<tr>
<td>COSTS (no land included)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: purchase 1st &amp; 2nd X weth. ($ 40.00/hd)</td>
<td>21600</td>
<td>21600</td>
<td>21600</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>sheep: purchases (ewes) ($ 26.00/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>6240</td>
<td>0.</td>
</tr>
<tr>
<td>fencing: one hot wire</td>
<td>1144</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>burning</td>
<td>4592</td>
<td>4592</td>
<td>4592</td>
<td>4592</td>
<td>4592</td>
</tr>
<tr>
<td>goats: variable costs</td>
<td>0.</td>
<td>1912</td>
<td>1912</td>
<td>212</td>
<td>212</td>
</tr>
<tr>
<td>sheep: variable costs ($ 3.54/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>1169</td>
<td>1169</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>27436</td>
<td>4072</td>
<td>4072</td>
<td>7861</td>
<td>1621</td>
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<tr>
<td>NET CASH FLOW</td>
<td></td>
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</tr>
<tr>
<td>-27436</td>
<td>3623</td>
<td>3623</td>
<td>17360</td>
<td>4191</td>
<td></td>
</tr>
<tr>
<td>CUMULATIVE CASH FLOW</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-27436</td>
<td>-23813</td>
<td>-20189</td>
<td>-2829</td>
<td>1362</td>
<td></td>
</tr>
<tr>
<td>IRR = 19.00%</td>
<td>NPV at 5% = $ 50117</td>
<td>Benefit Cost Ratio at 5% = 1.72</td>
<td></td>
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<td></td>
</tr>
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</table>
APPENDIX 12
GORSE CONTROL DEVELOPMENT BUDGETS USING GOAT OPTION 3

GOAT OPTION: 3 current prices, 6 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICAL DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of goats (initial goats = 6.00/ha)</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>240</td>
<td>240</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td>0.0</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td>0.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
</tr>
<tr>
<td>RETURNS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: progeny - meat ($ 7.00/hd)</td>
<td>0.0</td>
<td>534</td>
<td>534</td>
<td>178</td>
<td>178</td>
</tr>
<tr>
<td>sheep: (wool $ 2.87/kg) (lambs $ 14.77/hd)</td>
<td>0.0</td>
<td>3718</td>
<td>3718</td>
<td>4957</td>
<td>4957</td>
</tr>
<tr>
<td>goats: sales - feral does ($ 13.00/hd)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>1599</td>
<td>0.0</td>
</tr>
<tr>
<td>TOTAL RETURN</td>
<td>0.0</td>
<td>4252</td>
<td>4252</td>
<td>6734</td>
<td>5135</td>
</tr>
<tr>
<td>COSTS (no land included)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: purchase - feral does ($ 13.00/hd)</td>
<td>2399</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>sheep: purchases (ewes) ($ 26.00/hd)</td>
<td>4680</td>
<td>0.0</td>
<td>0.0</td>
<td>1560</td>
<td>0.0</td>
</tr>
<tr>
<td>fencing: one hot wire</td>
<td>1144</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>burning</td>
<td>100.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>topdressing</td>
<td>4592</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: variable costs ($ 1.92/hd)</td>
<td>0.0</td>
<td>345.0</td>
<td>345.0</td>
<td>115.0</td>
<td>115.0</td>
</tr>
<tr>
<td>sheep: variable costs ($ 4.87/hd)</td>
<td>0.0</td>
<td>877.0</td>
<td>877.0</td>
<td>1169.0</td>
<td>1169.0</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>12915</td>
<td>1221</td>
<td>1221</td>
<td>2844</td>
<td>1284</td>
</tr>
<tr>
<td>NET CASH FLOW</td>
<td>-12915</td>
<td>3031</td>
<td>3031</td>
<td>3890</td>
<td>3851</td>
</tr>
<tr>
<td>CUMULATIVE CASH FLOW</td>
<td>-12915</td>
<td>-9884</td>
<td>-6853</td>
<td>-2963</td>
<td>888</td>
</tr>
</tbody>
</table>

IRR = 25.90% NPV at 5% = $ 61240. Benefit Cost Ratio at 5% = 2.54
APPENDIX 12 (cont.)

GOAT OPTION: 3 current prices, 18 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL DATA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of goats</td>
<td>(initial goats = 18.00/ha)</td>
<td>540.</td>
<td>540.</td>
<td>540.</td>
<td>60.</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>240.</td>
<td>240.</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td>0.0</td>
<td>4.50</td>
<td>4.84</td>
<td>4.67</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td>0.0</td>
<td>90.0</td>
<td>95.6</td>
<td>92.6</td>
<td>90.0</td>
</tr>
<tr>
<td><strong>RENTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>goats: progeny - meat</td>
<td>($) 7.00/hd</td>
<td>0.</td>
<td>1603.</td>
<td>1603.</td>
<td>178.</td>
</tr>
<tr>
<td>sheep: (wool -$2.87/kg)(lams $14.77/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>5166.</td>
<td>4957.</td>
</tr>
<tr>
<td>goats: sales - feral does</td>
<td>($) 13.00/hd</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>6396.</td>
</tr>
<tr>
<td><strong>TOTAL RETURN</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.</td>
<td>1603.</td>
<td>1603.</td>
<td>1740.</td>
<td>5135.</td>
<td></td>
</tr>
</tbody>
</table>

| **COSTS (no land included)** | | | | | |
| goats: purchase - feral does | ($) 13.00/hd | 7196. | 0. | 0. | 0. | 0. |
| sheep: purchases (ewes) | ($) 26.00/hd | 0. | 0. | 0. | 6240. | 0. |
| fencing: one hot wire | | | | | |
| burning | 1144. | 100. | | | |
| topdressing | | | 4592. | | |
| goats: variable costs | ($) 1.92/hd | 0. | 1035. | 1035. | 115. | 115. |
| sheep: variable costs | ($) 4.87/hd | 0. | 0. | 0. | 1169. | 1169. |
| **TOTAL COSTS** | 13032. | 1035. | 1035. | 7524. | 1284. |
| **NET CASH FLOW** | -13032. | 568. | 568. | 4217. | 3851. |

IRR = 2.00% NPV at 5% = $52682. Benefit Cost Ratio at 5% = 2.21
APPENDIX 13

GORSE CONTROL DEVELOPMENT BUDGETS USING GOAT OPTION 4

GOAT OPTION: 4 current prices, 6 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL DATA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of goats</td>
<td>(initial goats = 6.00/ha)</td>
<td>180.</td>
<td>180.</td>
<td>180.</td>
<td>60.</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td></td>
<td>0.0</td>
<td>4.50</td>
<td>4.50</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td></td>
<td>0.0</td>
<td>90.0</td>
<td>90.0</td>
<td>90.0</td>
</tr>
</tbody>
</table>

| RETURNS | | | | | | |
| goats: progeny - 1st. cross does ($ 80.00/hd) | | 0. | 5760. | 5760. | 1920. | 1920. |
| - scrub vths. ($ 13.00/hd) | | 0. | 936. | 936. | 312. | 312. |
| sheep: (wool $ 2.87/kg) (lamb $ 14.77/hd) | | 0. | 3718. | 3718. | 4957. | 4957. |
| goats: sales - feral does ($ 13.00/hd) | | 0. | 0. | 0. | 1560. | 0. |
| - angora bucks ($250.00/hd) | | 0. | 0. | 0. | 750. | 0. |

| TOTAL RETURN | | 0. | 10414. | 10414. | 9499. | 7189. |

| COSTS (no land included) | | | | | | |
| goats: purchase - feral does ($ 13.00/hd) | | 2340. | 880. | 880. | 293. | 293. |
| - angora bucks ($250.00/hd) | | 1250. | 225. | 225. | 75. | 75. |
| sheep: purchases (ewes) ($ 26.00/hd) | | 4680. | 0. | 0. | 1560. | 0. |
| fencing: one hot wire | | 1144. | | | | |
| burning | | | | | | |
| topdressing | | | | | | |
| goats: variable costs ($ 1.89/hd) | | 0. | 341. | 341. | 114. | 114. |
| sheep: variable costs ($ 4.87/hd) | | 0. | 877. | 877. | 1169. | 1169. |

| TOTAL COSTS | | 14106. | 2322. | 2322. | 3211. | 1651. |

| NET CASH FLOW | | -14106. | 8092. | 8092. | 6288. | 5538. |

| CUMULATIVE CASH FLOW | | -14106. | -6014. | 2078. | 8366. | 13904. |

IRR = 49.23%  NPV at 5% = $ 101411.  Benefit Cost Ratio at 5% = 3.10
APPENDIX 13 (cont.)

GOAT OPTION: 4 current prices, 18 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4+</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICAL DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>no. of goats</td>
<td>(initial goats = 18.00/ha)</td>
<td>540.</td>
<td>540.</td>
<td>540.</td>
<td>60.</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>240.</td>
<td>240.</td>
</tr>
<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td>0.0</td>
<td>4.50</td>
<td>4.84</td>
<td>4.67</td>
<td>4.50</td>
</tr>
<tr>
<td>lambing %</td>
<td>0.0</td>
<td>90.0</td>
<td>95.6</td>
<td>92.6</td>
<td>90.0</td>
</tr>
</tbody>
</table>

RETURNS

| | | | | | |
| goats: progeny - 1st. cross does ($ 80.00/hd) | 0. | 17280. | 17280. | 1920. | 1920. |
| - scrub wth. ($ 13.00/hd) | 0. | 2808. | 2808. | 312. | 312. |
| sheep: | | | | | |
| (wool $ 2.87/kg) (lambs $ 14.77/hd) | 0. | 0. | 0. | 5166. | 4957. |
| goats: sales - feral does ($ 13.00/hd) | 0. | 0. | 0. | 6240. | 0. |
| - angora bucks ($250.00/hd) | 0. | 0. | 0. | 3000. | 0. |

TOTAL RETURN

| | | | | | |
| | 0. | 20088. | 20088. | 16638. | 7189. |

COSTS (no land included)

| | | | | | |
| goats: purchase - feral does ($ 13.00/hd) | 7020. | 2640. | 2640. | 293. | 293. |
| - angora bucks ($250.00/hd) | 3500. | 675. | 675. | 75. | 75. |
| sheep: purchases (ewes) ($ 26.00/hd) | 1144. | 0. | 0. | 6240. | 0. |
| fencing: one hot wire | 100. | 4592. | | | |
| burning | | | | | |
| topdressing | | | | | |
| goats: variable costs ($ 1.89/hd) | 0. | 1022. | 1022. | 114. | 114. |
| sheep: variable costs ($ 4.87/hd) | 0. | 0. | 0. | 1169. | 1169. |

TOTAL COSTS

| | | | | | |
| | 16356. | 4336. | 4336. | 7891. | 1651. |

NET CASH FLOW

| | | | | | |
| | -16356. | 15752. | 15752. | 8748. | 5538. |

CUMULATIVE CASH FLOW

| | | | | | |
| | -16356. | -604. | 15148. | 23895. | 29434. |

IRR = 76.42% NPV at 5% = $ 113585. Benefit Cost Ratio at 5% = 3.09
**APPENDIX 14**

GORSE CONTROL DEVELOPMENT BUDGET USING THE CHEMICAL METHOD WITH QUICK DEVELOPMENT RATE

CHEMICAL OPTION  quick rate development, current prices

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6+</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>PHYSICAL DATA</th>
<th>proportion of potential (%)</th>
<th>0.0</th>
<th>60.0</th>
<th>85.0</th>
<th>100.0</th>
<th>100.0</th>
<th>100.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>no. of sheep</td>
<td></td>
<td>162</td>
<td>230</td>
<td>270</td>
<td>270</td>
<td>270</td>
<td>270</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RETURNS</th>
<th></th>
<th>0. 3346.</th>
<th>4751.</th>
<th>5577.</th>
<th>5577.</th>
<th>5577.</th>
<th>5577.</th>
</tr>
</thead>
<tbody>
<tr>
<td>sheep: (wool $ 2.87/kg) (lambs $ 14.77/hd)</td>
<td></td>
<td>0. 3346.</td>
<td>4751.</td>
<td>5577.</td>
<td>5577.</td>
<td>5577.</td>
<td>5577.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOTAL RETURN</th>
<th></th>
<th>0. 3346.</th>
<th>4751.</th>
<th>5577.</th>
<th>5577.</th>
<th>5577.</th>
<th>5577.</th>
</tr>
</thead>
</table>

| COSTS (no land included) | sheep: purchase (ewes) ($ 26.00/hd) | 4212. | 1755. | 1053. | 0. 0. 0. 0. |
|--------------------------|--------------------------------------|-------|-------|-------|----------|----------|
| burning                  |                                       | 100.  |       |       |          |          |
| topdressing              |                                       | 4592. |       |       |          |          |
| chemical 2,4,5-T         | high vol. ($ 15.37/1)                 | 2306. | 692.  | 692.  | 692.  692.  692.  540.|
|             | low vol. ($ 45.79/ha)                | 1374. |       |       |          |          |
| helicopter application   |                                       | 0. 458. | 458.  | 458.  | 458.  458.  458.  458.  0.|
| sheep: variable costs    | low vol. ($ 15.25/ha)                | 0. 789. | 1120. | 1315. | 1315.  1315.  1315.  1315.|
|--------------------------|--------------------------------------|-------|-------|-------|----------|----------|

| TOTAL COSTS             |                                      | 12583. | 3693. | 3322. | 2464.  2464.  2464.  1855. |
|-------------------------|--------------------------------------|-------|-------|-------|----------|----------|
| NET CASH FLOW           |                                      | -12583. | -347. | 1428. | 3113.  3113.  3113.  3722. |

| IRR = 20.18% | NPV at 5% = $ 54393. | Benefit Cost Ratio at 5% = 2.00 |
APPENDIX 15

GORSE CONTROL DEVELOPMENT BUDGET USING THE CHEMICAL METHOD WITH MEDIUM (1) DEVELOPMENT RATE

CHEMICAL OPTION  medium (1) rate development, current prices

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6+</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICAL DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>proportion of potential (%)</td>
<td>0.0</td>
<td>33.0</td>
<td>66.0</td>
<td>77.0</td>
<td>89.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>89</td>
<td>178</td>
<td>208</td>
<td>240</td>
<td>270</td>
<td>270</td>
<td>270</td>
</tr>
<tr>
<td>RETURNS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep: (wool $ 2.87/kg) (lambs $ 14.77/hd)</td>
<td>0.</td>
<td>1838.</td>
<td>3676.</td>
<td>4296.</td>
<td>4957.</td>
<td>5577.</td>
<td>5577.</td>
</tr>
<tr>
<td>TOTAL RETURN</td>
<td>0.</td>
<td>1838.</td>
<td>3676.</td>
<td>4296.</td>
<td>4957.</td>
<td>5577.</td>
<td>5577.</td>
</tr>
<tr>
<td>COSTS</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no land included)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep: purchase (ewes)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($ 26.00/hd)</td>
<td>2314.</td>
<td>2319.</td>
<td>772.</td>
<td>842.</td>
<td>772.</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>burning</td>
<td>100.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>toprunning</td>
<td>4592.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chemical 2,4,5-T</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($ 15.37/1)</td>
<td>2306.</td>
<td>692.</td>
<td>692.</td>
<td>692.</td>
<td>692.</td>
<td>692.</td>
<td>540.</td>
</tr>
<tr>
<td>helicopter application - high vol. ($ 45.79/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1374.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- low vol. ($ 15.25/ha)</td>
<td>0.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>0.</td>
</tr>
<tr>
<td>sheep: variable costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>($ 4.87/hd)</td>
<td>0.</td>
<td>433.</td>
<td>867.</td>
<td>1013.</td>
<td>1169.</td>
<td>1315.</td>
<td>1315.</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>10685.</td>
<td>3902.</td>
<td>2788.</td>
<td>3005.</td>
<td>3090.</td>
<td>2464.</td>
<td>1855.</td>
</tr>
<tr>
<td>NET CASH FLOW</td>
<td>-10685.</td>
<td>-2064.</td>
<td>888.</td>
<td>1292.</td>
<td>1867.</td>
<td>3113.</td>
<td>3722.</td>
</tr>
</tbody>
</table>

IRR = 18.37%  NPV at 5% = $ 51568.  Benefit Cost Ratio at 5% = 1.97
**APPENDIX 16**

**GORSE CONTROL DEVELOPMENT BUDGET USING THE CHEMICAL METHOD WITH MEDIUM (2) DEVELOPMENT RATE**

**CHEMICAL OPTION medium (2) rate development, current prices**

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6+</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PHYSICAL DATA</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>proportion of potential (%)</td>
<td>0.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>162.</td>
<td>189.</td>
<td>216.</td>
<td>243.</td>
<td>270.</td>
<td>270.</td>
<td>270.</td>
</tr>
<tr>
<td><strong>RETURNS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep : (wool $ 2.87/kg) (lambs $ 14.77/hd)</td>
<td>0.</td>
<td>3346.</td>
<td>3904.</td>
<td>4461.</td>
<td>5019.</td>
<td>5577.</td>
<td>5577.</td>
</tr>
<tr>
<td><strong>TOTAL RETURN</strong></td>
<td>0.</td>
<td>3346.</td>
<td>3904.</td>
<td>4461.</td>
<td>5019.</td>
<td>5577.</td>
<td>5577.</td>
</tr>
<tr>
<td><strong>COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(no land included)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep : purchase (ewes)</td>
<td>($ 26.00/hd)</td>
<td>4212.</td>
<td>702.</td>
<td>702.</td>
<td>702.</td>
<td>702.</td>
<td>0.</td>
</tr>
<tr>
<td>burning</td>
<td>100.</td>
<td>4592.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>topdressing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>chemical 2,4,5-T</td>
<td>($ 15.37/l)</td>
<td>2306.</td>
<td>692.</td>
<td>692.</td>
<td>692.</td>
<td>692.</td>
<td>692.</td>
</tr>
<tr>
<td>helicopter application - high vol.</td>
<td>($ 45.79/ha)</td>
<td>1374.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- low vol.</td>
<td>($ 15.25/ha)</td>
<td>0.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
</tr>
<tr>
<td>sheep : variable costs</td>
<td>($ 4.87/hd)</td>
<td>0.</td>
<td>789.</td>
<td>920.</td>
<td>1052.</td>
<td>1183.</td>
<td>1315.</td>
</tr>
<tr>
<td><strong>TOTAL COSTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12583.</td>
<td>2640.</td>
<td>2772.</td>
<td>2903.</td>
<td>3035.</td>
<td>2464.</td>
<td>1855.</td>
</tr>
<tr>
<td><strong>NET CASH FLOW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CUMULATIVE CASH FLOW</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

IRR = 19.26%  
NPV at 5% = $ 52856.  
Benefit Cost Ratio at 5% = 1.99
**APPENDIX 17**

GORSE CONTROL DEVELOPMENT BUDGET USING THE CHEMICAL METHOD WITH SLOW DEVELOPMENT RATE

**CHEMICAL OPTION** slow rate development, current prices

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEAR</th>
<th>0.</th>
<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
<th>5.</th>
<th>6.</th>
<th>7.</th>
<th>8+</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICAL DATA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>proportion of potential (%)</td>
<td>0.0</td>
<td>30.0</td>
<td>40.0</td>
<td>50.0</td>
<td>60.0</td>
<td>70.0</td>
<td>80.0</td>
<td>90.0</td>
<td>100.0</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>81.</td>
<td>108.</td>
<td>135.</td>
<td>162.</td>
<td>189.</td>
<td>216.</td>
<td>243.</td>
<td>270.</td>
<td>270.</td>
</tr>
</tbody>
</table>

**RETURNS**

| sheep: (wool $ 2.87/kg) (lams $ 14.77/hd) | 0. | 1673. | 2231. | 2788. | 3346. | 3904. | 4461. | 5019. | 5577. |
| | | | | | | | | | |

**TOTAL RETURN**

| 0. | 1673. | 2231. | 2788. | 3346. | 3904. | 4461. | 5019. | 5577. | |

**COSTS** (no land included)

| sheep: | purchase (ewes) ($ 26.00/hd) | 2106. | 702. | 702. | 702. | 702. | 702. | 702. | 0. |
| burning ($ 10.00) | 100. | | | | | | | |
| topdressing | 4592. | | | | | | | |
| chemical 2,4,5-T ($ 15.37/1) | 2306. | 692. | 692. | 692. | 692. | 692. | 540. | 540. | 540. |
| helicopter application - high vol. ($ 45.79/ha) | 1374. | | | | | | | |
| - low vol. ($ 15.25/ha) | 0. | 458. | 458. | 458. | 458. | 458. | 0. | 0. | 0. |
| sheep: variable costs ($ 4.87/hd) | 0. | 394. | 526. | 657. | 789. | 920. | 1052. | 1183. | 1315. |
| | | | | | | | | | |
| TOTAL COSTS | 10477. | 2246. | 2377. | 2509. | 2640. | 2772. | 2294. | 2425. | 1855. |

**NET CASH FLOW**

| -10477. | -573. | -146. | 280. | 706. | 1132. | 2167. | 2594. | 3722. |

**CUMULATIVE CASH FLOW**


**IRR = 16.06%** **NPV at 5% = $ 46915.** **Benefit Cost Ratio at 5% = 1.92**
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