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THE ECONOMICS OF CONTROLLING GORSE IN HILL COUNTRY COMPARING GOAT AND SHEEP GRAZING COMBINATIONS WITH THE CHEMICAL METHOD

A thesis submitted in partial fulfilment of the requirements for the degree of Master of Commerce (Agriculture) in the University of Canterbury

by

M.A. Krause

Lincoln College

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The aim of this study was to assess the economics of controlling gorse in hill country, comparing the use of goat and sheep grazing to 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 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. Due to the limited data available a deterministic approach was taken. Extensive sensitivity analysis and experimentation was carried out to evaluate alternative control strategies under different price and production scenarios. The model was also constructed to be useful for future analysis and agricultural extension.

The study concludes with a discussion of the results given both long and short term expectations. A brief outline of the scope for further study in this topic is also given.
Keywords: gorse control; chemical; goats; sheep; economic analysis; simulation; limited data; partial budget; sensitivity analysis; deterministic model; complimentary grazing.
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To my wife Lucy, I offer special thanks for patience, understanding and invaluable support given during my study. This thesis is dedicated to her.

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CHAPTER 1

INTRODUCTION

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 657000 ha. 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 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. 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

* Blanket spraying implies a full coverage with chemical of the total area infested with gorse.
control by the use of correct goat management may well be a viable and effective alternative to the traditional method.

One way in which New Zealand can improve livestock production is to improve the production potential of hill country. The use of goat and sheep grazing to reclaim gorse infected hill 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 as 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 has been 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

* Spot spraying implies the individual spraying of gorse plants by a hand held device.
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. 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 had 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 preferentially browse gorse 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). 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 Necessity of studying this problem.

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.

To the best of the author's knowledge, no study of this type has been carried out on this problem. 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 affects could be ignored. The 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 assessed the treatment 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, 1983). 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. Similarly in this trial to
determine stocking pressure, 2 goats were equated to 1 sheep. Even though the reassessment of stocking rates were made during both trials, the proportions of sheep to goats were maintained (Rolston et al, 1981a; Radcliffe et al, 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 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
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 this relationship 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. Therefore goats are better equipped physically for browsing gorse.

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 2.2. Figure 2.1 illustrates the measured growth of gorse at Ballantrae and together with Figure 2.2
FIGURE 2.1: GORSE GROWTH RATE RECORDED AT THE BALLANTRAЕ TRIAL (Rolston et. al., 1981a)

FIGURE 2.2: AVERAGE GORSE HEIGHT UNDER DIFFERENT GOAT STOCKING RATES AT THE BALLANTRAЕ TRIAL (Rolston et. al., 1981a)
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.

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 2.3. These figures were derived from an annual percentage change in gorse height. While both trials had different levels of gorse density and different trial commencement dates, they both indicate 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 a decreasing marginal control of gorse relationship 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, these 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
FIGURE 2.3: FIRST YEAR CHANGE IN GORSE HEIGHT TO GOAT STOCKING RATES IN THE BALLANTRAЕ AND LOBURN TRIALS
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 and have demonstrated definite control of gorse.

Feral goats appear to be the only practical type of goat available to 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 unsuitable for weed control due to problems with their long coats getting entangled in scrub and gorse (Batten, 1979b). Thus, using angoras for gorse eradication would 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.

Farmers may consider up-grading 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, if they are successful they will yield a greater financial return than the common feral goat enterprises. However, good 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 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.

Sheep show signs of controlling gorse growth only under mob stocking grazing management. (Rolston et al, 1981a; Radcliffe, 1982). Thus, sheep will eat gorse only when forced.

(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 2.4 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 2.2. These results were also evident in the Loburn trial (Radcliffe, 1982). It would appear, therefore, that for sheep to have any control over gorse, mob stocking management is needed. Sheep allowed to graze under normal stocking rates offer no control over gorse.

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. It appears that sheep actively select clover because it is a high quality feed. 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 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
FIGURE 2.4: AVERAGE GORSE HEIGHT UNDER DIFFERENT SHEEP STOCKING RATES IN THE BALLANTRAЕ TRIAL (Rolston et. al., 1981a)
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 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 actively select clovers in preference to grasses, and goats actively 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 2.5, 2.6, 2.7 and 2.8 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 2.5 and 2.6 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 2.7 and 2.8). 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

Clark et al (1982) estimate the degree of competitive grazing by calculating the Kuluyznski’s similarity coefficient. This coefficient is estimated by sampling the intake by goats and sheep of the pasture species type on offer. The coefficient is measured using the following formula:
FIGURE 2.5: 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 2.6: 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 2.7: 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 2.8: 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)
\[ S = \frac{2w}{a + b} \]

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

\[ a = \text{sum of the diet components (per cent) for sheep} \]
\[ b = \text{sum of the diet components (per cent) for goats.} \]

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

Figure 2.9 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, seen in Figure 2.9. 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.
FIGURE 2.9: SEASONAL SIMILARITY COEFFICIENTS FOR GOAT AND SHEEP GRAZING TREATMENTS IN THE BALLANTRAE TRIAL (Clark et. al., 1982)
(3) Ewe live weights

The performance of ewe live weights in the Ballantrae Trial also illustrates the benefits of complementary grazing with goats. In Figure 2.10 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.

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 reduce any pasture production and thus prevent viable sheep grazing.

The growth pattern of gorse is similar to pasture, as seen in Figure 2.11, 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.
FIGURE 2.10: LIVEWEIGHT OF EWES IN THE BALLANTRAЕ TRIAL

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Treatment</th>
<th>Sheep %</th>
<th>Goats/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>Jun</td>
<td>33% Sheep</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Jan</td>
<td>33% Sheep</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Jun</td>
<td>66% Sheep</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Jul</td>
<td>66% Sheep</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Aug</td>
<td>66% Sheep</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Sep</td>
<td>66% Sheep</td>
<td>6</td>
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</tr>
<tr>
<td>1980</td>
<td>Oct</td>
<td>66% Sheep</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Nov</td>
<td>66% Sheep</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>Dec</td>
<td>66% Sheep</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Jan</td>
<td>100% Sheep</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Feb</td>
<td>100% Sheep</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Mar</td>
<td>100% Sheep</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>Apr</td>
<td>100% Sheep</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1981</td>
<td>May</td>
<td>100% Sheep</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1981</td>
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<td>100% Sheep</td>
<td>0</td>
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<tr>
<td>1981</td>
<td>Jul</td>
<td>100% Sheep</td>
<td>0</td>
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<tr>
<td>1981</td>
<td>Aug</td>
<td>100% Sheep</td>
<td>0</td>
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<td>1981</td>
<td>Sep</td>
<td>100% Sheep</td>
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<td>1981</td>
<td>Oct</td>
<td>100% Sheep</td>
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<td>1981</td>
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<td>100% Sheep</td>
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<tr>
<td>1981</td>
<td>Dec</td>
<td>100% Sheep</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 2.11: COMPARISON OF PASTURE AND GORSE GROWTH PATTERNS AT THE BALLANTRAE TRIAL (Rolston, et. al., 1981a)

- Pasture
- Gorse

GORSE GROWTH RATE (mm/day)

PASTURE GROWTH (kg/ha/day)

MONTHS
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). Gorse is therefore a difficult weed to control.

The main weakness in the life-cycle of gorse is that in the early stages of growth it does not compete well with pasture (Rolston, 1981a; Meeklah, 1981). Maintaining a good producing pasture should therefore prevent 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).

2.3.2 Pasture.

Good pasture management is essential for optimal animal production and the prevention of weeds. Pasture species will compete successfully with weed species 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 closely assessed if optimal pasture production is to be regained.

The growth rate of pasture in hill country is shown in Figure 2.11. 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 accurately known, it would appear that the encouragement of clover production in hill country is most important in pasture management.

Pasture will compete well against gorse seedlings (Meeklah, 1981) but not against established gorse plants. Once established gorse plants are brought under control by goats, and given adequate fertility, pasture will readily compete for the area previously under gorse (Rolston, 1983). Thus, pasture production will increase proportionately as effective gorse cover is decreased.

2.3.3 Use of chemicals.

(1) Effect on gorse

The use of chemicals in controlling gorse is quite common and is recommended by the M.A.F. Of the herbicides, 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 dependant 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 .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 dessicating the plants encourages a good burn (Matthews, 1975). Regrowth after burning can then be controlled by spot spraying.

(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 indicate 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) states that 2,4,5-T has a detrimental effect on clover production and research reported by Maclean (1957) indicates 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) 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 economic 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 (Bramely et al, 1967). Hence there is a 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).
2.5 Climatic Effects

The effect of climate on the gorse control system is suspected to be minimal (Clark and Rolston, 1983). 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. Pasture production is affected by climate, but since climate affects the control of gorse under chemical or grazing strategies to a similar extent, it is not vital to this study. Given adequate shelter and management, climate should also have a minimal effect on sheep production. Therefore, any effect climate may have on this system is minimal and was not considered.
CHAPTER 3

THE ECONOMIC AND MANAGEMENT CHARACTERISTICS CONCERNING
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

Due to its nature, the control of gorse requires a long term management plan for a complete check or eradication to be obtained. Gorse is not only resistant to grazing, but the seed can remain dormant for up to thirty years, giving the weed a potential to become re-established if not kept in check. Follow-up work in any gorse control program is essential as gorse may reinfest to even greater densities. The control of gorse therefore requires a program that will be effective over a period of years.

The area of gorse infestation to be redeveloped differs 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 effect 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

The approach of using goats to control gorse is not a new practice, but interest in this method has been renewed due to the increasing cost of using chemicals. The traditional method is to burn the stand of gorse during the late spring or summer months. 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 (Radcliffe and Rolston 1983). 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 always be required to help prevent reversion. A maintenance stocking rate of goats can be run with the sheep flock, as goats will control gorse with minimal competition to the sheep for pasture.

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. However, the recent popularity of using goats for scrub and weed control has meant that feral progeny can currently obtain higher prices being sold for scrub control than for meat sales. Current cashmere* prices coupled with

* Cashmere is the under down of a feral goat and is the finest fibre obtained from goats.
the discovery that a proportion of feral goats in New Zealand can produce commercial quantities of cashmere, has meant there are potential 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

The use of chemicals will result in a quicker control of gorse infested country but at a higher cost than goats (Ritchie, 1979; 1982). Chemical control has traditionally been the method recommended by the M.A.F. It 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 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

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

** Mohair is a fibre only obtained from Angora goats and is not as fine as cashmere and cashgora fibres.
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 stock orientation is for spring lambing, only the spring kidding management is considered. Management timing relating to spring kidding is shown in Figure 3.1. 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
FIGURE 3.1: MANAGEMENT STRATEGY FOR
SPRING KIDDING
(Batten, 1979c)

KIDDING STARTS

DOES KIDDING

KIDDING ENDS

UNMATED YOUNG

MARKING MUSTER

DOES AND KIDS

SLAUGHTER STOCK
MUSTER

MUSTER ALL STOCK, BUCKS WITHDRAWN

WEANED YOUNG STOCK

WEANING MUSTER
DIP ALL STOCK
DRENCH YOUNG STOCK
BUCKS INTRODUCED TO BREEDING DOES
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). In this analysis a kidding rate of 80 per cent was assumed.

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 be quite high if there is not adequate shelter (Horgan, 1979). A 10 per cent death rate was selected, based on experience at Ballantrae (Clark and Rolston, 1983). 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 are 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). This wire will prevent goats pushing under the fence, the usual method of 'testing' fences (Horgan, 1979).

(iii) grazing management

As mentioned above, control of gorse is a long term project. A
maintenance stocking rate of goats is expected to be a good form of long term control (Rolston, 1983). 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) 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 in a confined mob stocking situation. Thus, mob stocking could produce health and behavioural problems (Batten, 1982). Horgan (1979) on the other hand suggests that goats rotationally grazed 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). 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 gorse at a higher infested density (Radcliffe and Rolston, 1983). The major disadvantage with rotational grazing is that a higher fencing cost is incurred. The
majority of data available is relevant to gorse infested at a lower density; set stocking is therefore assumed adequate for this condition.

(2) Sheep

Sheep management has been well researched and improved practices are widely used. An example of this information was given by Owen (1976). Thus, a detailed discussion of this was 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 characterised by 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 wethers 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 then 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., 1983).

(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 (Morris, 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). 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). 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). Therefore a large supply of feral does and available selection time is 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 micron obtaining the highest price. A great deal of genetic gain can be achieved if farmers approach cashmere production seriously (Parkinson, 1983). 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 demand is far greater than supply (Moyland, 1983).
(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). 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).

(6) Sheep products

Sheep products include lambs and wool. Both of these items are marketed by Producer Boards within New Zealand and are 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 assessed in this analysis. The four were chosen as being representative of the options available. The four enterprise types are:

(a) dry feral does and wethers with income from cashmere production,

(b) first and second cross wethers with income from cashgora production,

(c) self replacing feral doe herd with surplus kids sold for meat,

(d) 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), 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 spot spray is required to check faster 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. The sheep required for mob stocking were assumed to come 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.

The mob stocking of sheep has been attempted as a complete method to reclaim gorse infested country. This technique however, has met with limited success in both the Ballantrae and Loburn trials. This treatment has controlled some plants while letting other plants grow uncontrolled. Complete suppression of gorse does not appear possible using this method (Radcliffe and Rolston, 1983).

During redevelopment it is expected that the carrying capacity of the land will improve and eventually reach full potential. A self replacing Romney ewe flock was used to assess the changing earning capacity of the redeveloped land. This flock had the same management and physical characteristics as the goat/sheep gorse control method outlined in section 3.3.1 (2).
3.4.2 Cost and returns for chemical and mob stock grazing.

(1) General cost and returns

Estimating 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.

Mob stocking is an integral part of this form of gorse control. However, no costs or financial benefits were assumed to come from the use of mob stocking.

Spot spraying is another common form of spraying gorse. The cost effectiveness of spot spraying depends on the size and density of plants. Thus, at times it may be preferred to blanket spraying. It was assumed for this analysis that spot spraying is only a maintenance method of preventing regeneration of gorse once it has been fully controlled by blanket spraying.

Topdressing is also required to aid pasture establishment. This option was costed in the same manner as outlined for the goat/sheep method in Section 3.3.3 (1).

(2) Costs specific to this study

The permanent sheep enterprise carried on the 30 hectares during redevelopment was similar to that outlined in section 3.3.3 (2).
CHAPTER 4

THE MODEL

4.1 Introduction

The development of a simulation model is very much an evolutionary process. Components of the system are isolated and then individually simulated within modules. The model construction process involves a number of stages often occurring simultaneously. Modules are built guided by the data and subjective expectations, verified and then validated. If the modules are inadequate in simulating any specific part of the system, they must be either altered or rebuilt and the building process repeated. Hence the evolutionary process. In this chapter the development of the model is described together with some of the verification and validation undertaken during model construction.

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 model, construction was designed to provide flexibility of analysis. Sensitivity analysis is the major tool used in assessing the economic differences between the chemical and the goat/sheep grazing methods in controlling gorse.
The majority of data were taken from the Ballantrae trial. The treatments results from this 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). These treatments will be directly referred to as the number of goats or sheep grazed per hectare. This expression coincides with the hypothesis that gorse control is directly related to the number of goats per hectare.

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.

While these aspects are different, verification must occur before validation but if validation proves the model to be inadequate, the model must be adjusted and re-verified and validated. This process occurs both during model construction when modules are tested and at the completion of model construction when the model is tested as a whole.

Since model evaluation occurs both during model construction and at
the completion of model building, the description of model evaluation will be appropriately 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 such as the Turing type test 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 strongly influenced by the data availability and in this system, data are quite limiting. For the goat/sheep method for controlling gorse there are, as previously mentioned, two trial sites generating data. These are 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 is to assess the effectiveness of goats and sheep controlling gorse under different grazing combinations.

Both trials have provided data on goat grazing rates to 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, 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 grazing equivalent of a goat commenced 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 by equating a goat 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). Hence, subjective judgement based on both trials was valid 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 is 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 are deficiencies in the Ballantrae trial data, the Loburn trial data was used as a guide.

Data are also scarce on the effects of chemicals on gorse control 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 2,4,5-T effect on clover production. Therefore detailed modelling of the chemical option of gorse control is also difficult given the data availability.

4.3.2 Deterministic model

One of the strengths of simulation is its ability to handle risk and uncertainty through the use of a stochastic approach. However, to incorporate stochasticity within a model, data must be available upon which to base the estimates for the necessary probability distributions. If these data are not available, then little confidence can be placed in any estimated probability distribution, which diminishes the benefits of using stochasticity in handling uncertainty. Considering the data limitations in this study, a stochastic approach to the model was rejected. Instead, uncertainty was allowed for through sensitivity analysis.

A major area of uncertainty in many agricultural systems is the effect of climate. There are limited data available on the climatic effects on gorse growth. As gorse growth however, is felt not to be affected greatly by climatic variation, climate would have limited effect on the system being studied (Clark and Rolston, 1983). Any influence that does occur will equally effect the chemical or goat/sheep method and hence it was assumed unnecessary to allow for climatic effects within this model.
The two 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).

4.3.3 The general system

A general structure diagram of the system being studied is given in Figure 4.1. The two distinct sections of the model are the goat/sheep method and the chemical method. Both sections are brought together in the economic analysis for comparisons to be made.

The goat/sheep method comprises four modules. The first module deals with relationships between the goat grazing pressure and the level of gorse control. Different levels of goat grazing pressure give rise to different clover content within the pasture. This relationship is handled by the next module. Goats and sheep have different grazing preferences and depending on the pasture composition, are either complementary or competitive grazers. The goat/sheep grazing complementary module assesses the degree of complementarity or competitiveness and the quantity of pasture on offer, and determines the amount of pasture available per animal. The animal production module assesses the appropriate animal production parameters depending on feed availability. The final module accepts the animal production parameters and calculates the economic results given the various economic parameters.

The chemical method of the system is handled in a similar manner. Chemical is applied in varying quantities throughout the redevelopment phase. This aspect of the system is largely dependant 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 module deals with these relationships. The animal production module calculates the animal production parameters given the number of animals carried and the available pasture production. Similarly, the economic module accepts the animal production parameters and given the economic parameters, assesses the economic implications of the particular option for controlling gorse.

4.4 Time Interval

The time step of a model is largely dependant 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 4.1

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 to goat grazing at Ballantrae was done using gorse height. Figure 4.2 indicates the height variation of the 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:

\[ y = -4.31 + 1.42 x \]

(1)

\( (3.24) (0.16) \)

\( R\text{-squared} = 91.2 \text{ per cent, adjusted for D.F.} \)

where:  \( y = \text{effective gorse cover (\%)} \)

\( x = \text{gorse height (cm)} \)

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 predicting power of this estimate. In the absence of other evidence, it was assumed that this same relationship holds for the Ballantrae trial.

To give validity in simulating effective gorse cover, subjective estimates by D.S.I.R. scientists of were also taken into account. Their estimates, shown in Figure 4.3, indicate that effective gorse cover is
FIGURE 4.2: GORSE HEIGHT MEASUREMENTS FROM THE BALLANTRAE TRIAL

- 0 goats/ha
- 6 goats/ha
- 12 goats/ha
- 18 goats/ha

GORSE HEIGHT (cm)

1979
Trial Starts

1980
MONTHS
FIGURE 4.3: EXPECTED EFFECTIVE GORSE COVER CHANGES TO VARIOUS GOAT GRAZING RATES (Clark & Rolston, 1983)
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 4.2 and the subjective estimates of Figure 4.3. However, a few alterations to the height information had to be made. These alterations are listed below with the results shown in Figure 4.4.

(a) From Figure 4.3, 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 4.2. Since an indication for a quarterly time step was needed and the 18 goats per hectare treatment gave the more expected result, the 12 goats per hectare observations were ignored.

(b) It would appear from Figure 4.3 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 4.2). The extra data points required were then estimated by relating the required height decline to the gorse growth pattern given in Figure 2.1. The extrapolated points from August 1980 to April 1981 are shown in Figure 4.4.

(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 2.1. The extrapolated values are plotted in Figure 4.4 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 4.1. From these figures effective gorse cover changes were simulated.
By plotting the three observations from each quarter and then estimating a function by eye through these three points, a relationship representing each quarter could be estimated. The relationships for July 1979 and October 1979 are given in Figure 4.5 and 4.6 respectively. These relationships from the basis to estimate the effective gorse cover in each quarter for the first two years, for any goat grazing proportion within 9 S.U. per hectare.

**TABLE 4.1**
**Extrapolated Effective Gorse Cover Estimates for the Ballantrae Trial**

<table>
<thead>
<tr>
<th>TREATMENTS</th>
<th>0 GOATS Per Hectare</th>
<th>6 GOATS Per Hectare</th>
<th>18 GOATS Per Hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (Quarter)</td>
<td></td>
<td></td>
<td></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>
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<tr>
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<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>
FIGURE 4.5: ESTIMATED RELATIONSHIP AFTER THE FIRST QUARTER BETWEEN THE PROPORTION OF GOAT GRAZING AND EFFECTIVE GORSE COVER

July 1979 Quarter: 1

FIGURE 4.6: ESTIMATED RELATIONSHIP AFTER THE SECOND QUARTER BETWEEN THE PROPORTION OF GOAT GRAZING AND EFFECTIVE GORSE COVER

October 1979 Quarter: 2
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 4.3. 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 treatment. 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.).

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 pressure on the clover content of the pasture,

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

(c) The degree of complementary or competitive grazing between goats and sheep.

These aspects affect the sheep production during gorse redevelopment.
Goats are assumed to be of major importance in gorse control and any financial return is of secondary benefit. Given these assumptions, the above aspects will be considered with respect to estimating sheep production.

(1) Clover content of pastures.

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). Figure 4.7 indicates the difference in per cent clover on offer. The result is as generally expected; the higher the proportions of goats to control gorse, the less heavily grazed was the clover. This specific relationship is confused a little when considering both the 6 and 12 goats per hectare treatments. Clover content in the pasture for the 12 goats per hectare treatment is expected to be higher than the 6 goats per hectare treatment. Also, clover content from these two treatments should lie between the bounds set by 18 and 0 goats per hectare treatments. These expected characteristics are not evident, as seen in Figure 4.7. However, because there are no replicates to support statistical testing or to determine the reason for the unexpected results from the 6 and 12 goats per hectare treatments, judgement could only be subjective. Therefore it was assumed that the figures observed for the 18 and 0 goats per hectare treatments represent the extremes of what can be expected in clover variation. A direct linear relationship of clover on offer to goat grazing rates between the two extremes is also assumed. Any variation between 0 and 18 goats per hectare is then allocated the corresponding clover on offer estimate. Quarterly
FIGURE 4.7: PERCENTAGE CLOVER PRESENT IN THE PASTURE AT THE BALLANTRAEE TRIAL

![Graph showing the percentage of clover present in the pasture at the Ballantrae trial over the months of 1980 and 1981. The graph includes lines for different goat densities (18 goats/ha, 12 goats/ha, 6 goats/ha, and 0 goats/ha) throughout the months.]
estimates can be made for the first two years of gorse control from data in Figure 4.6.

Once the gorse is controlled to zero effective per cent cover, the grazing ratios of goats to sheep are changed. From that stage a maintenance of two goats per hectares is needed with the remaining grazing potential for sheep. Any clover built up in the pasture will benefit sheep production, especially when the change in grazing ratios is made. After one year of normal sheep grazing, the clover percentage on offer is assumed to return to normal levels (the level recorded for the 0 goat per hectare situation) (Thompson, 1983).

During the initial gorse control, the model determines the proportion of clover on offer by calculating the appropriate relationship, given the goat grazing pressure. Once there is no effective gorse cover, the grazing proportion of sheep is increased and clover on offer is decreased over the next four quarters. The clover on offer decrease is related to expected clover seasonal production patterns and is declined to the level of clover expected for the 0 goats per hectare treatment.

(2) Pasture Production Characteristics.

Given that clover production varies with the proportion of goats, it would 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 4.8, there appeared to be no significant response in pasture production. Pasture production from all treatments follows the expected seasonal pattern without any obvious differences occurring. Statistical
FIGURE 4.8: PASTURE PRODUCTION FROM THE BALLANTRAЕ TRIAL TREATMENTS

DRIY MATTER PASTURE (kg/ha)

MONTHS

1979 1980 1981

J J A S O N D J F M A M J J A S O N D J F M A
procedures testing for significant differences can not be applied because there are no replicates. Therefore, subjectively it is assumed that no differences occur between treatments and no pasture production changes need to be allowed for.

The modelling of pasture production was made by calculating the average daily growth rate over all the treatments from the Ballantrae trial and then calculating the appropriate quarterly pasture production figures. The quarterly pasture production per hectare estimates are listed in Table 4.2.

<table>
<thead>
<tr>
<th></th>
<th>D.M./ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn</td>
<td>2322</td>
</tr>
<tr>
<td>Winter</td>
<td>2016</td>
</tr>
<tr>
<td>Spring</td>
<td>4185</td>
</tr>
<tr>
<td>Summer</td>
<td>4455</td>
</tr>
</tbody>
</table>

The quarterly D.M. production available for sheep grazing was calculated from these data.
Modelling complementary and competitive grazing.

In simulating this aspect of the system, information is required on goat diet selection given different types of feed on offer. Unfortunately this information is not known for the extensive grazing situation, so an alternative approach was taken. The only guide to the degree of competitiveness or complementarity of grazing between sheep and goats is by the measure of the diet similarity coefficient \( S \). This parameter is calculated by sampling diet intake of fistulated goats and sheep grazing the various treatments of the Ballantrae trial and measures the degree of complementary grazing between the two types of animals. A more detailed explanation of the diet similarity coefficient is given in Chapter 2, section 2.2.3 (2). Thus, given that proportions of pasture and weed species on offer (grass, clover, gorse and thistles) largely determine the degree of competitive or complementary grazing, it was hypothesised that the proportion of these species on offer should provide the basis for a reasonable prediction of the diet similarity coefficient \( S \). Given the two years of quarterly data available for estimated diet similarity coefficients and proportions of grass, clover, gorse and thistle in the pasture, regression analysis was used to determine the relationship. After assessing a number of functions the following regression was found to be the best estimate.

\[
y = 1.03 - 0.0091 X_1 - 0.0075 X_2 - 0.0037 X_3
\]

(2)

\[
(0.07) (0.0010) (0.0027) (0.0014)
\]

R-squared = 72.6 per cent, adjusted for D.F.

where:
\[ y = \text{diet similarity coefficient 'S'}, \]

\[ x_1 = \text{extrapolated gorse per cent cover}, \]

\[ x_2 = \text{per cent clover on offer (point analysis)}, \]

\[ x_3 = \text{percentage of thistles in the diet (data from fistulated animals)}. \]

This estimate is thought to be reasonable since all variable coefficients are significant at the 5 per cent level and the adjusted R-square indicates a 73 per cent explanation of the variation in the dietary coefficient.

The coefficient values and signs are logical since goats prefer gorse and thistles to clover, and sheep prefer clover. Thistles were included in the regression since they were present during the first summer period of the Ballantrae trial. Proportions of grass on offer did not improve the regression estimates.

Extrapolated gorse cover (Variable \( x_1 \)) was the estimated gorse cover given in equation (1) and the gorse height measurements from the Ballantrae trial. Clover data (Variable \( x_2 \)) came from the point analysis surveys of the Ballantrae treatments while the proportion of thistles in the diet (Variable \( x_3 \)) was only available from the samples taken from the fistulated animals.

Given that (i) the percentage clover on offer can be simulated (section 4.5.2 (1)), (ii) pasture production can be estimated (section 4.5.2 (2)), (iii) the diet similarity factor 'S' can be predicted and (iv) the proportion of goats is known, the following method was developed to estimate the complementary/competitive grazing
effects. The method is described using the diagram presented in Figure 4.9 and using an hypothesised example. The diagram conceptually represents one hectare of pasture with the horizontal axis representing the proportion of goats and sheep being grazed while the vertical axis represents the diet similarity index. In this example, the simulated gorse cover, per cent clover on offer and thistle values are substituted into regression (2) and the resultant diet similarity coefficient 'S' is estimated to be 0.8. The 'S' value is placed on the axis showing 80 per cent of the pasture being common to both goats and sheep, and 20 per cent being uncommon. This example has a third of the grazing pressure coming from goats. At 6 goats per hectare with 0.5 S.J. per goat, the goat grazing pressure is a third of the 9 S.J. per hectare. This value is represented on the horizontal axis indicating the proportion of pasture available to goats and sheep respectively.

FIGURE 4.9
EXAMPLE ILLUSTRATING THE METHOD FOR THE CALCULATION OF COMPLEMENTARY/COMPETITIVE GRAZING BETWEEN GOATS AND SHEEP

<table>
<thead>
<tr>
<th>1.0</th>
<th>D</th>
<th>A</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(uncommon)</td>
<td>(common)</td>
<td>diet similarity coefficient 'S'</td>
</tr>
<tr>
<td>0</td>
<td>0.33</td>
<td>1.0</td>
</tr>
<tr>
<td>(goats)</td>
<td>(sheep)</td>
<td>proportion of goats grazing gorse</td>
</tr>
</tbody>
</table>
The areas of available pasture can then be allocated to either goats or sheep. The section marked D in Figure 4.9 is assumed to represent gorse since it is in the area eaten only by goats. Since gorse is not a part of the D.M. pasture production, this area does not affect the allocation of pasture production to goats and sheep. Assuming that the period is autumn and 2322 kg of D.M. is produced, the associated proportions occupied by A and B of the diagram represent pasture availability to sheep with area C being the goats' portion of the pasture.

This method then assesses the degree of complementary/competitive grazing and given the proportion of goat grazing, the pasture available can be allocated between goats and sheep. The more complementary the grazing, the larger the areas D and A would become and vice versa. Different goat grazing stocking rates would also result in alterations in the allocation of pasture.

Assessing the percentage of clover using this method requires the assumption that clover is consumed only by sheep and gorse is consumed only by goats. Hence, the per cent clover on offer in the pasture must be recalculated so that clover is only included in the pasture available to sheep. The percentage of clover on offer to the sheep is then slightly higher than the percentage on offer in the total pasture.

(4) Validation of the pasture system.

The sections of the simulation described in sections 1 to 3 above were programmed into the model to determine the validity of this logic.
The program has a quarterly time step and goes through three different pasture phases:

(a) gorse cover is declining and clover per cent in pasture is altering depending on the proportion of goats;

(b) once gorse cover is zero, grazing ratios are altered and clover, depending on prior goat treatment, decreases to normal levels over the next four quarters;

(c) clover proportions have returned to normal in the pasture.

An example of the results of modelling the gorse and pasture components is given in Table 4.3. For each quarter the D.M. pasture production per sheep, clover percentage on offer in the sheep diet, per cent gorse cover and the diet similarity coefficient 'S' are given.

The example given in Table 4.3 illustrates the goat/sheep method commencing with 10 goats per hectare. The three pasture phases can be seen as the simulation progresses, with the first phase occurring as gorse cover is declining. This phase shows a relatively high clover per cent on offer. The second phase commences when gorse cover is zero which triggers off the change in grazing ratios and continues for the next four quarters. At this phase, the per cent clover is decreasing down to the level expected when a higher proportion of sheep are grazing the pasture. The final phase in this example starts at the second quarter of year four, with normal levels of clover percentage on offer. This phase continues until the end of the simulation.

The subroutines that handle this section of the simulation are given in both Appendix 10 and 11 with the major subroutine GOATS in Appendix 11. A description of how these subroutines operate in the model is given in Appendix 13.
The results from this procedure, similar to the example given in Table 4.3, were discussed with an experienced Animal Production Specialist * to ascertain the sheep production parameters expected from the type of pasture and clover availability, and to determine the validity of the figures being generated. The validity exercise can be viewed as a type of Turing Test. In his opinion the percentage clover on offer was within the ranges that could be expected, but D.M. pasture production was approximately double that which the animal could consume.

The expected D.M. requirements for a ewe for the three months of each season are given in Table 4.4 (Thompson, 1983). The comparative figures generated by the model, using the first year's figures outlined in Table 4.3, are listed in Table 4.4. For pasture production to be used as a guide to animal production, it must be assumed that all pasture production is consumed. Clearly from these comparisons a ewe could not utilize the quantity of feed estimated by the model and so the model has failed to be valid for use under this assumption. This result reflects the problem of under utilization of pasture experienced in the first few years of the Ballantrae trial. It also reflects the problem of experimental treatments obtaining higher than average pasture and animal production levels. An example of increased production from an experimental treatment occurred on a sheep production trial at Ruakura. Record pasture production was well above district averages (Rattray et al, 1978) and lambing percentages were approximately 40 per cent above district averages (Jagusch et al, 1978). Brougham (1977) also notes the phenomena of higher animal and pasture production from experiments being consistently higher than district farming levels.

* K. Thompson, Lincoln College
TABLE 4.3
Quarterly Output from the Gorse and Pasture Simulation
Using an Initial 10 Goat per Hectare Example

<table>
<thead>
<tr>
<th>TIME</th>
<th>D.M. Production per sheep</th>
<th>Clover % of Feed available to sheep</th>
<th>Gorse Cover %</th>
<th>Diet Similarity Coefficient 'S'</th>
</tr>
</thead>
<tbody>
<tr>
<td>YEAR 1</td>
<td>QRT 1</td>
<td>254.54</td>
<td>39.19</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td>QRT 2</td>
<td>208.43</td>
<td>21.76</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>QRT 3</td>
<td>432.45</td>
<td>20.81</td>
<td>1.80</td>
</tr>
<tr>
<td></td>
<td>QRT 4</td>
<td>503.44</td>
<td>56.63</td>
<td>2.62</td>
</tr>
<tr>
<td>YEAR 2</td>
<td>QRT 1</td>
<td>253.46</td>
<td>41.45</td>
<td>3.32</td>
</tr>
<tr>
<td></td>
<td>QRT 2</td>
<td>209.69</td>
<td>23.31</td>
<td>2.05</td>
</tr>
<tr>
<td></td>
<td>QRT 3</td>
<td>460.15</td>
<td>48.89</td>
<td>1.51</td>
</tr>
<tr>
<td></td>
<td>QRT 4</td>
<td>495.13</td>
<td>54.66</td>
<td>0.87</td>
</tr>
<tr>
<td>YEAR 3</td>
<td>QRT 1</td>
<td>253.49</td>
<td>49.24</td>
<td>0.22</td>
</tr>
<tr>
<td></td>
<td>QRT 2</td>
<td>203.49</td>
<td>16.90</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 3</td>
<td>423.06</td>
<td>18.86</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 4</td>
<td>449.91</td>
<td>17.58</td>
<td>0.00</td>
</tr>
<tr>
<td>YEAR 4</td>
<td>QRT 1</td>
<td>233.37</td>
<td>11.19</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 2</td>
<td>201.94</td>
<td>6.74</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 3</td>
<td>420.60</td>
<td>11.19</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 4</td>
<td>448.49</td>
<td>13.41</td>
<td>0.00</td>
</tr>
<tr>
<td>YEAR 5</td>
<td>QRT 1</td>
<td>233.37</td>
<td>11.19</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 2</td>
<td>201.94</td>
<td>6.74</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 3</td>
<td>420.60</td>
<td>11.19</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>QRT 4</td>
<td>448.49</td>
<td>13.41</td>
<td>0.00</td>
</tr>
</tbody>
</table>
TABLE 4.4

Expected D.M. Requirement and Estimated Available D.M.
Per Ewe for the Three Months of Each Season

<table>
<thead>
<tr>
<th>SEASON</th>
<th>EXPECTED KILOGRAMS D.M. REQUIREMENT PER EWE</th>
<th>ESTIMATED KILOGRAMS D.M. AVAILABILITY PER EWE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Autumn</td>
<td>130</td>
<td>255</td>
</tr>
<tr>
<td>Winter</td>
<td>90</td>
<td>208</td>
</tr>
<tr>
<td>Spring</td>
<td>270</td>
<td>432</td>
</tr>
<tr>
<td>Summer</td>
<td>90</td>
<td>503</td>
</tr>
</tbody>
</table>

Adjustments to make the model more applicable include:

(a) alter the pasture production pattern,
(b) evaluate ewe live weight changes obtained from the Ballantræ trial as a guide to clover benefits to sheep production.

Altering the pasture production estimates is a possible approach but determining the more correct pasture production may produce less practical results. It was also felt that assessing the benefit of clover percentage on offer would be difficult even if the model was producing valid results (Thompson, 1983). Research information indicating the quantitative relationships between the percentage clover on offer and ewe production parameters in a farm situation is limited. Therefore, the approach of altering pasture production is only feasible
once research knowledge quantifying the clover benefits to ewe and lamb production in the farm situation is improved*. This meant that ewe live weights were assessed for indication of increased clover benefits.

(5) Ewe live weights to assess Clover Benefit

Since ewe live weights were available from the Ballantrae trial it was proposed to use these figures to indicate any likely benefit from increased clover production. The ewe live weight variations are shown in Figure 2.10 (see section 2.2.3 (2)). Again there are no replicates, so no statistical analysis of significance can be made. From the data shown in Figure 2.10 it would appear 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 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).

* The subroutines necessary to use the procedure described above are however still operative in the model to allow for the improvement of research knowledge in the future, when this method of monitoring pasture production and consumption would be appropriate.
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) and deal with expected lambing percentages and total wool clip per ewe.

\[ A = (2 \times B) + 5 \]  \hspace{1cm} (3)

where:

\begin{align*}
A & = \text{number of lambs tailed}, \\
B & = \text{ewe live weight at mating}.
\end{align*}

\[ C = 0.1 \times D \]  \hspace{1cm} (4)

where:

\begin{align*}
C & = \text{total wool clip per ewe}, \\
D & = \text{mean annual live weight per ewe}.
\end{align*}

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 4.5. 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 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). The differences that have occurred could
TABLE 4.5

Estimated Lambing Percentage and Wool Clip Given Ewe Live Weights from the Second Year of the Ballantrae Trial

<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 (12 Goats per hectare)</td>
<td>114.3</td>
<td>5.56</td>
</tr>
<tr>
<td>6 Sheep per hectare (6 Goats per hectare)</td>
<td>108.3</td>
<td>5.12</td>
</tr>
<tr>
<td>9 Sheep per hectare (0% Goats per hectare)</td>
<td>108.9</td>
<td>5.21</td>
</tr>
</tbody>
</table>

be due to the smaller size of the experimental treatments. Thus, the ewe live weights are higher than those expected for the district and so are decreased to expected district levels. The ewe live weight differences between 3 and 9 sheep per hectare are maintained except that the 9 sheep per hectare ewe live weight is lowered to the expected level. The sheep production parameters in the second year of the model are listed in Table 4.6.

TABLE 4.6

Animal Production Parameters Used for the Second Year in the Model

<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 (12 Goats per hectare)</td>
<td>95.6</td>
<td>4.84</td>
</tr>
<tr>
<td>9 &amp; 6 Sheep per hectare (6 &amp; 0 Goats per hectare)</td>
<td>90.0</td>
<td>4.50</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 obtained 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 is assumed that this benefit will only remain for the first year after the change and only half the benefit will occur in this year.

Figure 4.10 and 4.11 illustrate these assumptions and how the model has dealt with them. For both the ewe wool cut and the lambing percentage, the maximum benefit is achieved in the second year, halved in the following year and back to normal in the final and subsequent years. The method of using ewe live weights is thought to be a valid way of assessing clover benefits within the model.
**FIGURE 4.10: 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 4.11: 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 6 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 invested areas. A survey was taken of M.A.F. advisors who have had experience of advising spray options for gorse control and have observed the results. Table 4.7 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. Subroutine CHEM listed in Appendix 11 has been constructed so that in simulating the chemical option, the rate of recovery can be varied to any combination of up to ten years.
TABLE 4.7
Advisor’s Expectations of Pasture Carrying Potential During a Spray Gorse Control
(Proportion of Potential Carrying Capacity)

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

The figures given in Table 4.7 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 represent the range of development rates that can be expected. It is assumed that the same chemical spray program is used and thus this range of development reflects the variation in management skills. The best management skills obtaining the quickest development rate.

4.7 Modelling of the Economic Analysis

The approaches to economic analysis available for this study are a whole farm analysis or a partial analysis. Whole farm analysis assess enterprises and financial aspects concerning all parts of the
farm. Only aspects of the farm directly related to the decision of what method to use in gorse control are assessed in a partial analysis. A partial analysis approach was chosen for a number of reasons. Firstly, a whole farm approach would require greater detail in modelling to allow for all aspects of the farm. Most of the whole farm activities have no direct effect on the gorse control program. Hence, the benefit of extending the model to involve the whole farm would be minimal in deciding what gorse control program to undertake. Secondly, in using a whole farm approach, a case study with specific financial constraints would have to be assumed. This restricts the relevance of analysis to that type of farm with these financial constraints. Thus the generated results would have limited extension value. Thirdly, a partial analysis by definition assesses aspects only directly related to the problem being studied. This concentrates the study on isolating the specific advantages and disadvantages of using each method. Fourthly, a partial analysis can be done regardless of the constraints imposed on the remainder of the farm. A farmer or advisor can then assess the results for financial implications to the specific farm. This means the results obtained from a partial analysis are more relevant to most farmers than a more restricted whole farm approach. Assumptions must be made within a partial analysis but these assumptions are generally not as restricting as a whole farm approach.

The economic analysis has been based on generating a development budget within the partial analysis framework. From the 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 can be calculated. These measurements are then
assessed for the economic advantage or disadvantage in both the goats/sheep and chemical methods of controlling gorse.

In calculating the NPV and benefit cost ratios, a real interest rate was appropriate since all figures within the development budget are 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 the 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 continues the development budget until the year 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 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 proposed methods.

There are difficulties associated with the measurement of IRR due to the possibility of multiple interest solutions (Dasgupta and Pearce, 1972). The IRR measurement is only useful when the annual cash flow moves from negative to positive and remains positive.

The financial calculations are performed in the subroutine GCALC for the goat/sheep method and in the subroutine CHEM for the chemical method. Both subroutines are listed in Appendix 11. The 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 number 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 are based on the gross margins listed in Appendix 2 to 6.

Examples of the development budget generated by the model are listed in Appendices 14 to 21. The example given in the Appendices are of current costs and returns. The specific examples given include:
APPENDIX 14 - gorse control with goats using dry ferals and income from cashmere

APPENDIX 15 - gorse control with goats using first and second cross wethers with income from cashgora

APPENDIX 16 - gorse control with goats using feral does with progeny sold for meat

APPENDIX 17 - gorse control with goats using feral does cross to angora with doe kids sold as first cross and wether kids for scrub clearance

APPENDIX 18 - gorse control with chemicals, quick term development

APPENDIX 19 - gorse control with chemicals, medium (1) term development

APPENDIX 20 - gorse control with chemicals, medium (2) term development

APPENDIX 21 - gorse control with chemicals, slow term development

The time period for the development budget assessing the chemical option is dependent on the redevelopment phase. The model can assess up to 10 years. A minimum of 6 years is set because the spray routine goes for 5 years and the sixth year is required for the steady state calculation.

4.8 The Refined Model

4.8.1 Model structure.

The model is constructed in a modular form and accesses a series of subroutines. One data file (DAT.DAT) contains the necessary information
for the main program to call the specific subroutines and perform the required analysis. The data file is accessed directly and stores information required by most subroutines. This design was used so the model can be run in batch mode if required. A diagram of the subroutines shown in Figure 4.12, gives an outline of how the model is constructed. All subroutines used by the model are listed in Appendix 11.

FIGURE 4.12
STRUCTURE OF THE MODEL

PROGRAM MAIN

SUBROUTINE GORSE

SUBROUTINE GOATS

SUBROUTINE CHEM

SUBROUTINE WOOLLB

SUBROUTINE SHEEPC

SUBROUTINE GCALC

SUBROUTINE SHEEPR

SUBROUTINE IRRNPV
The goat/sheep method of the model is simulated by the main subroutines GOATS and GCALC. Subroutine GOATS determines the status of gorse cover with the aid of subroutine GORSE, and the associated animal production parameters by accessing subroutine WOOLLB. Once the gorse has declined to zero cover, and pasture and clover on offer have returned to normal, the physical simulation has been completed. The subroutine GOATS then passes on the animal numbers, associated production parameters and the number of years required for redevelopment through to subroutine GCALC for the economic assessment and construction of the development budget. This subroutine calls subroutine SHEEP to assess the sheep capital requirements and subroutine SHEEP to ascertain the gross returns from sheep during redevelopment. Subroutine GCALC also accesses the data file for most of the economic information needed to calculate the development budget. The subroutine IRRNPV is accessed to determine most of the economic measurements required in assessing economic viability. Subroutine GCALC also organises the development budget to be placed in the sequentially organized data file RES.DAT. This file can be printed at the completion of the run to view the results. Organisation of the goat/sheep development budget also involved manipulation of character strings so that the correct headings are used for the respective goat enterprise costs and returns. An example of this can be seen when comparing the headings in the development budgets of Appendix 14 to 17. This character string handling is also performed by subroutine GCALC.

The chemical method is simulated in the subroutine CHEM. Redevelopment simulation for the method depends mainly on the length of time required for full potential grazing to be reached. This aspect is
stored in the data file DAT.DAT. Subroutine CHEM performs the physical aspects of the simulation, the appropriate economic calculations and the organisation of the development budget placed on the sequential data file RES.DAT. Subroutine CHEM accesses the data file DAT.DAT for the specific economic parameters to aid the necessary economic calculations. Subroutine IRRNPV is also called to calculate the economic performance indicators. Examples of the development budget for this method are listed in Appendix 18 to 21.

4.8.2 Flexibility of the model.

The concept of placing most of the data required for running the model on a data file was designed to facilitate flexibility and aid the sensitivity analysis. Alteration of the data file is all that is required to assess the sensitivities of the model. Aspects that can easily be changed include all the economic parameters and a few physical parameters. The values that can be altered easily via the data file are listed on Table 4.8. The parameters that can be varied are numerous and necessary for the sensitivity analysis that is required.

The model has also been built to be interactive and hence has a number of characteristics termed "user-friendly". A program called SET.FOR was created to allow easy adjustments to be made to the data file that runs the model. The structure of this program was based on a series of menus which show the options that can be changed and allow the user to alter any of these options. The running structure of the model is illustrated in Figure 4.13. Thus, the model can either be operated interactively or organized in batch mode.
TABLE 4.8

List of Variables that can be Altered Via the Data File

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>VARIABLES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goat/Sheep : general</td>
<td>- initial goat stocking rate (goats/ha)</td>
</tr>
<tr>
<td>: dry feral cashmere enterprise</td>
<td>- price of feral goats ($/hd)</td>
</tr>
<tr>
<td>: first and second cross wether goats</td>
<td>- price of first and second cross</td>
</tr>
<tr>
<td>: feral does with progeny as meat</td>
<td>- price of feral does ($/hd)</td>
</tr>
<tr>
<td>: feral does cross to angora</td>
<td>- price of feral does ($/hd)</td>
</tr>
<tr>
<td>Chemical : general</td>
<td>- price of 2,4,5-T</td>
</tr>
<tr>
<td>: general</td>
<td>- price of 2,4,5-T</td>
</tr>
<tr>
<td>: sheep</td>
<td>- price of 2,4,5-T</td>
</tr>
<tr>
<td>: selection</td>
<td>- the selection of the goat/sheep</td>
</tr>
<tr>
<td></td>
<td>or chemical method</td>
</tr>
<tr>
<td>General</td>
<td>- price of 2,4,5-T</td>
</tr>
<tr>
<td>: selection</td>
<td>- the selection of the goat/sheep</td>
</tr>
<tr>
<td></td>
<td>or chemical method</td>
</tr>
</tbody>
</table>
The program SET.FOR is listed in Appendix 12 and uses various library functions for screen formatting purposes. This allows the menus and the questions to be set out neatly on the screen, giving this program "user-friendly" characteristics. The user, while in the SET.FOR program, is also given the ability to view all the data on the data file that can be varied. This ensures the data alterations can be assessed to be correct before exiting and running the simulation model.

FIGURE 4.13
INTERACTIVE STRUCTURE OF THE MODEL

The neatness and layout of results in the development budget also allow for ease of interpretation. As can be seen from development budget examples listed in Appendices 14 to 21, most of the economic parameters are incorporated within each budget. This allows each run to be relatively self explanatory. The ability to place a title above each development budget is also given, allowing relatively detailed explanation of each model run. Presenting the economic parameters and the detailed financial and physical information in the development budget printout allows the user to undertake some validation, which encourages confidence in the model. Result presentation also assists in making the model "user-friendly".
The model has been constructed to be beneficial to users other than the developer. The development budget generated is self explanatory and allows for ease of interpretation. Flexibility built into the model aids sensitivity analysis and allows the model to be relevant in the future when economic parameters have altered.

To aid in creating the data file (DAT.DAT) the program INSET.FOR was written. A listing of this program is given in Appendix 12. All current data (1983) required to run the model is also inserted into the data file by this program.

4.8.3 Comments on the model.

The final performance of the model is more dependent on subjective judgement than was initially planned. This has occurred because of the limitations of data within the relevant trials. An attempt to make the model more detailed in the simulation of the goat/sheep method failed due to the lack of data and scientific knowledge. The model now stands as a balanced model with no greater detail given to either gorse control methods. Slightly more economic attention has been given to the goat/sheep method due to the current instability within various goat product markets. This was necessary to allow for the expected market changes in some goat product markets and hence give increased validity to the results.
5.1 Introduction

The economics of the two methods of gorse control were determined in both short term and long term analysis. 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 beyond this range. Therefore, the estimated optimum goat grazing rates reported in this chapter should be viewed with 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:
(a) feral goats with income from cashmere, 
(b) first and second cross wether goats with income from cashgora, 
(c) feral does with income from progeny sold for meat, 
(d) 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 5.1. 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 best NPV per hectare being $3720.* 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 means that intrinsic economic considerations are likely to determine the optimum goat grazing rates. Since the sale of first cross kid does is 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 5.1. A positive slope indicates that the

* All NPV values were calculated with a discount rate of 5 per cent.
FIGURE 5.1: COMPARISON OF GOAT ENTERPRISE OPTIONS FOR GORSE CONTROL GIVEN CURRENT PRICES

<table>
<thead>
<tr>
<th>Initial Goats per Hectare</th>
<th>Option 1</th>
<th>Option 2</th>
<th>Option 3</th>
<th>Option 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

NPV @ 5% ($/ha)
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 5.1. 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 5.1**

<table>
<thead>
<tr>
<th>IRR Values from the Best Goat Grazing Rates for each Goat Option</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Option</strong></td>
</tr>
<tr>
<td>------------</td>
</tr>
<tr>
<td>1</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>3</td>
</tr>
<tr>
<td>4</td>
</tr>
</tbody>
</table>

(continued...
The development budget results for each goat option for both the 6 and 18 goat per hectare stocking rates are presented in Appendices 14 to 17. These results indicated that options 1, 2 and 3 each broke even in year four, while option 4 reached break even 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 5.1. 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 4.7, 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 5.2 and indicate the rate at which full grazing potential was reached. Variations in the rate of development is a reflection in the management skills of the farmer.
TABLE 5.2

The Development Rates Based on Pasture Carrying Capacity During Chemical Gorse Control
(Proportion of Potential Carrying Capacity)

<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>

Figure 5.2 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.
FIGURE 5.2: COMPARISONS OF THE DIFFERENT RATES OF DEVELOPMENT FOR CHEMICAL GORSE CONTROL GIVEN CURRENT PRICES

NPV @ 5% ($/ha)

0 500 1000 1500 2000

QUICK MEDIUM (1) MEDIUM (2) SLOW

RATE OF DEVELOPMENT
The IRR results for the various rates of development are given in Table 5.3. 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 18 to 21. 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 5.3

IRR Results for the Four Rates of Development in the Chemical Method

<table>
<thead>
<tr>
<th>Rate of Development</th>
<th>IRR (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick</td>
<td>40.6</td>
</tr>
<tr>
<td>Medium (1)</td>
<td>39.4</td>
</tr>
<tr>
<td>Medium (2)</td>
<td>40.1</td>
</tr>
<tr>
<td>Slow</td>
<td>29.5</td>
</tr>
</tbody>
</table>
5.2.3 Comparisons of goat/sheep and chemical options

A comparison of the four goat options and two of the chemical development strategies is shown in Figure 5.3. Estimated NPV ($/ha) indicate that while both were profitable, the goat/sheep options were more profitable than the chemical method. The NPV difference between the most favourable chemical development rate and the least favourable goat option was $260 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 5.1 and 5.3. All goat options gained higher IRR values than the most favourable chemical treatment.

Comparing the break even period for the various gorse control methods, the goat/sheep method achieved the break even point the quickest. The longest goat/sheep break even period was four years, while the shortest chemical break even 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.
FIGURE 5.3: 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)

1000 2000 3000 4000
5.2.4 The sensitivities of results

The results indicated conclusively that the goat/sheep method is more economic than the chemical method in the short term. This 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 therefore assessed in the sensitivity analysis. The quick and medium (1) rates of chemical development were seen to cover the expected rates of chemical development obtainable by most farmers.

(1) The price of 2,4,5-T

Figure 5.4 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 was $1980 and is marked by the dashed line in Figure 5.4. From Figure 5.4 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,
FIGURE 5.4: 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 ($/l)
given that goat and sheep markets remain stable at current levels.

(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 5.5. 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 5.5). 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.
FIGURE 5.5: EFFECT ON THE PROFITABILITY OF THE GOAT/SHEEP METHOD GIVEN DIFFERENT FERAL GOAT PRICES

PRICE OF FERAL GOATS ($/hd)
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 profitability between the two gorse control methods. Figure 5.6 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 have in controlling gorse.

5.3 The Long Term Situation

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 depleting 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
FIGURE 5.6: EFFECT ON THE PROFITABILITY OF THE GOAT/SHEEP METHOD GIVEN DIFFERENT PRICES RECEIVED FOR KID MEAT

prices received for kid meat ($/hd)

18 goats per hectare
6 goats per hectare

Current Price

NPV @ 5% ($/hd)
also assumed that the range of quick and medium (1) term chemical development reflects 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 5.7.

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 resulted 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 5.8. 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 to 62 per cent decrease in NPV ($/ha). The
FIGURE 5.7: EFFECT OF CHANGING SHEEP RETURNS ON THE GOAT/SHEEP METHOD OF GORSE CONTROL

NPV @ 5% ($/ha)

-40 -20 0 20

PERCENTAGE CHANGE FROM CURRENT SHEEP RETURNS

6 goats /ha
18 goats /ha
FIGURE 5.8: 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
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 converge as the decline in sheep return increases.

5.3.3 **Comparison of the two methods of gorse control**

Figure 5.9 indicates the NPV results for the best options of both gorse control methods under the declining sheep return situation given goat returns do not vary. 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 prices 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**
FIGURE 5.9: COMPARISON OF THE GOAT/SHEEP AND CHEMICAL METHODS OF GORSE CONTROL GIVEN VARYING SHEEP RETURNS
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 5.10 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, significant technological advancement is required if the chemical method is to be the most economic option.
FIGURE 5.10: 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

NPV @ 5% ($/ha)

PERCENTAGE DECREASE IN CURRENT CHEMICAL APPLICATION COSTS
CHAPTER 6
CONCLUSIONS

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 will be 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 preferable 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 for feral does used in gorse control if crossed with angora bucks. 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 (Moorehouse, 1983). 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 is the most profitable, the rate of development for the chemical method had relatively little effect on the final economic outcome. Chemical and application costs had a stronger influence on profitability. Any effort to improve the chemical method should 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 no 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 production prices 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, the chemical method will become more profitable than the goat/sheep method if sheep product prices increase 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, leaving the goat/sheep method as the only viable alternative. Similarly, the goat/sheep method would remain viable only until sheep product prices fell below 64 per cent of current costs and returns.

(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 improvement in technology.
6.2.5 Clover benefit due to goat grazing

Clover proportion in the pasture increases when the pasture is predominantly grazed by goats. This increased level of clover was assessed 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 aspects: 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 partial analysis
approach, which provides a detailed development budget describing the cash flows, should 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 aided experimentation and should permit the model to be valuable in any future analysis when current situations have changed. The 'user-orientated' design for operating the model should allow it to be easily used, and this should give it a potential in agricultural extension.

6.4 Scope for Future Research

The insensitivities of the model's results to changing economic parameters (Chapter 5) clearly illustrate 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 if goats could control gorse. While the trials differed slightly in their approach to the problem, both proved the value 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 preferred. This indicates that the optimum goat grazing
rate could well be below the range assessed. Goat management strategies would improve then, if the minimum goat grazing requirements for adequate gorse control were known. Further research is 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 (0, 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. In this trial it appears that gorse control is more sensitive to stocking pressure than at the Ballantrae trial (see Figure 2.3). At Loburn, not all treatments began with the same density of gorse and only two goat grazing pressures were involved (0, 10 and 20 goats per hectare). No strict comparisons can therefore be made between the Loburn and the Ballantrae trials. The results from the limited data presently available indicate that goat stocking rates required for effective gorse control are 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

In the present study, a method was devised to simulate competitive and complementary grazing between goats and sheep (see section 4.5.2). This method should be beneficial for similar studies into the management
of combined goat and sheep grazing, and thus reduce the need for further research into diet similarity between goats and sheep. However, due to the lack of clear understanding of the relationship between clover production levels and sheep production, this method could not be incorporated into this model. 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 this model is that 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. Therefore, future research into gorse control should be aimed at exploring the effect of regulating goat grazing pressure. This approach was not taken in either the Ballantrae or Loburn trials. Rather, treatments in these trials were based on goat to sheep stocking ratios. When pasture production was under-utilized, grazing pressures
were increased but the goat/sheep ratios were maintained. An alternative 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 alternative approach to gorse grazing research and management is economically justifiable, as most of the pasture would be utilized by the more profitable sheep enterprise. Therefore, the assessment of gorse control strategies in the future should be based on separate goat and sheep grazing pressures depending on gorse control required and pasture production available, and not on set goat/sheep grazing combinations.

(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 and 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 relate to 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 results. A strong linear relationship between gorse height and gorse cover was estimated from
Loburn data, which helped to extrapolate effective gorse cover. This would not have been necessary if adequate data on effective gorse cover were available from the Ballantrae trial. Collection of effective gorse cover estimates 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 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 supply rather than a weed, which alters the whole emphasis to 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 area for future research after the basic investigations on gorse control have been completed.
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Thompson, K. (1983), personal communication, 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 says.
APPENDIX 2

FERAL GOAT GROSS MARGIN: CASHMERE PRODUCTION

This example is of 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 even though losses occur. This gross margin estimate has been compiled with the aid of Moorhouse (1983), Parkinson (1983), Squire-Wilson (1983) and Woodwad (1983). The gross margin is given 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) 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 obtain the level of selection process suggested by Parkinson (1983) (approximately 1 goat selected in 20).

lower level = 100 gm fleece @ 30% yield @ $110/kg = $3.30/head
higher level = 200 gm fleece @ 50% yield @ $110/kg = $11.00/head

Production Parameters

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

Gross Revenue

500 goats @ $11.00/head cashmere $ 5500.00

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/kd 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

TOTAL VARIABLE COSTS 3455.00

TOTAL GROSS MARGIN 2045.00

Variable Cost per feral goat = $6.91

Gross Margin per feral goat = $4.09

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

FIRST AND SECOND CROSS ANGORA GOAT GROSS MARGIN:
CASHGORA PRODUCTION

This example is of 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) and Woodward (1983). The gross margin is of 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

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>
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. (0.5 S.U. = 1 goat) = $2.22
APPENDIX 4

FERAL GOAT GROSS MARGIN: KID MEAT PRODUCTION FOR BREEDING

This example is of 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). The gross margin example is based on a 500 feral doe herd.

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

Gross Margin

<table>
<thead>
<tr>
<th>Gross Return</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Kids 212 @ $7/head</td>
<td>1484.00</td>
</tr>
</tbody>
</table>

TOTAL GROSS REVENUE
1484.00

Variable Costs

<table>
<thead>
<tr>
<th>Goat health - does @ $1.44/head (based on equivalent ewe health costs listed in Appendix 6)</th>
<th>720.00</th>
</tr>
</thead>
<tbody>
<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>
</tbody>
</table>

TOTAL VARIABLE COSTS
1868.00

TOTAL GROSS MARGIN
384.00
Variable Cost per doe = $3.74
Gross Margin per doe = -$0.77
Gross Margin per S.U. (0.5 S.U. = 1 feral doe) = -$1.54
APPENDIX 5

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

This example is of 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) 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

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>TOTAL GROSS REVENUE</td>
<td>18600.00</td>
</tr>
</tbody>
</table>

Variable Costs

- Goat health - does @ $1.44/ head (based on equivalent ewe health costs listed in Appendix 6) $720.00
- Kids @ $0.33/head (based on equivalent lamb health costs listed in Appendix 6) $132.00

Purchase replacement feral does
50 @ $13/head $650.00
Purchase of replacement angora bucks
3 @ $250/head 750.00

Transport for replacements @ $0.50/head 27.00

Interest on livestock capital
500 feral does @ $13.00/head @ 14% 910.00
12 angora bucks @ $250.00/head @ 14% 420.00

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. (0.5 S.U. = 1 feral doe) = $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) and adjusted for the North Island hill country with aid from Pottinger (1983).

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

Production Parameters

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>Unit Price</th>
<th>Total Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lamb sales</td>
<td>511</td>
<td>$14.77</td>
<td>$7,547.47</td>
</tr>
<tr>
<td>(including skins and wool)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hill sheep sales</td>
<td>75</td>
<td>$15.00</td>
<td>$1,125.00</td>
</tr>
<tr>
<td>- 239 ewes</td>
<td></td>
<td>$7.00</td>
<td>$1,673.00</td>
</tr>
<tr>
<td>Wool Sales</td>
<td>4,500 kg</td>
<td>$2.87/kg net</td>
<td>$12,915.00</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>2,900 kg</td>
<td></td>
<td>$2.87/kg net</td>
<td>$5,998.30</td>
</tr>
<tr>
<td>(380 hoggets @ 5.5 kg allowing for deaths)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL GROSS REVENUE $29,258.77
### Variable Costs

<table>
<thead>
<tr>
<th>Item</th>
<th>Quantity/Details</th>
<th>Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shearing</td>
<td>1000 sheep @ $75/100</td>
<td>750.00</td>
</tr>
<tr>
<td></td>
<td>380 hoggets @ $75/100</td>
<td>285.00</td>
</tr>
<tr>
<td>Tup crutch</td>
<td>990 ewes @ $23/100</td>
<td>227.70</td>
</tr>
<tr>
<td>Main crutch</td>
<td>990 ewes @ $32/100</td>
<td>316.80</td>
</tr>
<tr>
<td>Drenching</td>
<td>2 drenches @ 13c/dose for 1015 (ewes drenched once before lambing)</td>
<td>263.90</td>
</tr>
<tr>
<td></td>
<td>lambs, 1850 doses @ 6.46c/dose, replacements drenched 3 times, stores twice, and primes once</td>
<td>119.51</td>
</tr>
<tr>
<td>Vaccination</td>
<td>triple vaccine, 980 ewes @ 14.57c/sheep</td>
<td>142.79</td>
</tr>
<tr>
<td></td>
<td>triple vaccine, 370 hoggets @ 14.57c/sheep</td>
<td>53.91</td>
</tr>
<tr>
<td>Eartags, footrot and docking</td>
<td></td>
<td>475.00</td>
</tr>
<tr>
<td>Dipping</td>
<td>990 ewes @ 27c/head</td>
<td>267.30</td>
</tr>
<tr>
<td></td>
<td>376 hoggets @ 27c/head</td>
<td>101.52</td>
</tr>
<tr>
<td></td>
<td>660 lambs @ 27c/head</td>
<td>178.20</td>
</tr>
<tr>
<td>Woolshed expenses</td>
<td>wool packs, twine, glue, emery paper and shearing plant expenses, approximate costs @ 30c/ewe and 17c/hogget</td>
<td>364.00</td>
</tr>
<tr>
<td>Ram costs</td>
<td>2 per 100, 4 year life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 @ $150/ram</td>
<td>750.00</td>
</tr>
<tr>
<td>Cartage</td>
<td>store lambs to yards 450 @ $1.00/head</td>
<td>450.00</td>
</tr>
<tr>
<td></td>
<td>cull two teeth and five year old to yards, 264 @ $1.57 each</td>
<td>414.48</td>
</tr>
<tr>
<td></td>
<td>cull ewes to works 50 @ $1.57 each</td>
<td>78.50</td>
</tr>
<tr>
<td></td>
<td>wool 5658 kg @ 4.8c/kg</td>
<td>271.58</td>
</tr>
<tr>
<td>Selling charges</td>
<td>yard fees 444 lambs @ 26c/lamb</td>
<td>115.44</td>
</tr>
<tr>
<td></td>
<td>commission $6726 @ 4.75%</td>
<td>319.49</td>
</tr>
<tr>
<td>Interest on livestock capital</td>
<td>(1370 ewes @ $26/head @ 14%)</td>
<td></td>
</tr>
</tbody>
</table>

**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 S.U. = 1 ewe) = $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).

Topdressing

<table>
<thead>
<tr>
<th></th>
<th></th>
<th>$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Superphosphate 500kg/ha @ $142/t (on farm)</td>
<td>71.00</td>
<td></td>
</tr>
<tr>
<td>Ruanui Ryegrass 25kg/ha @ $1.80/kg</td>
<td>45.00</td>
<td></td>
</tr>
<tr>
<td>Paroa Ryegrass 4kg/ha @ $2.40/kg</td>
<td>9.60</td>
<td></td>
</tr>
<tr>
<td>Huia White Clover 2kg/ha @ $4.50/kg</td>
<td>9.00</td>
<td></td>
</tr>
<tr>
<td>TOTAL COST PER HA</td>
<td>134.60</td>
<td></td>
</tr>
</tbody>
</table>

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 $134.60/ha @ 30 ha</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>
<tr>
<td>Total topdressing costs for 30 ha are</td>
<td>4591.60</td>
</tr>
</tbody>
</table>
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). This example assumes electricity needs to be brought from a mains 1 kilometer 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>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$600.00</strong></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 tensil 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>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$544.00</strong></td>
</tr>
</tbody>
</table>

Total fencing costs for the 30 ha is **$1144.00**
The costings of 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 220 l of water per hectare at a helicopter cost of $45.79
  - Total cost: $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 $15.25
  - Total cost: $23.06

**Maintenance Spraying**

Since gorse seeds have long dormancy periods, an outbreak of gorse is possible. Thus a maintenance spot spray can be used to check regeneration of gorse once the initial stand is entirely checked. A cost of $2.00 per S.U. is currently used by farmers for maintenance (Phillips, 1983). At a potential carrying capacity of 9 S.U./ha this maintenance cost is $18/ha.
APPENDIX 10

PROGRAM LISTING OF SUBROUTINES
USED IN SIMULATING COMPLEMENTARY GRAZING

Program listing of the subroutines for simulating pasture production, percentage clover on offer, complementary grazing between goats and sheep and feed availability for sheep production. These subroutines are written in FORTRAN 77 programming language.

SUBROUTINES:  
CLOV1.FOR  
CLOV2.FOR  
CLOV3.FOR  
CLOV4.FOR  
SHFD.FOR
C this subroutine calculates clover % in pasture
SUBROUTINE CLOVI(JYEAR, JQUAR, CLOVER, GPROP)
C year two
IF(JYEAR.EQ.2.AND.JQUAR.EQ.1) THEN
   CLOVER=19.
ELSEIF(JYEAR.EQ.2.AND.JQUAR.EQ.2) THEN
   CLOVER=10.
ELSEIF(JYEAR.EQ.2.AND.JQUAR.EQ.3) THEN
   CLOVER=4.+0.1*GPROP
ELSEIF(JYEAR.EQ.2.AND.JQUAR.EQ.4) THEN
   CLOVER=24.+0.08*GPROP
C year three
ELSEIF(JYEAR.EQ.3.AND.JQUAR.EQ.1) THEN
   CLOVER=9.+0.2*GPROP
ELSEIF(JYEAR.EQ.3.AND.JQUAR.EQ.2) THEN
   CLOVER=3.+0.14*GPROP
ELSEIF(JYEAR.EQ.3.AND.JQUAR.EQ.3) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.3.AND.JQUAR.EQ.4) THEN
   CLOVER=12.+0.27*GPROP
C year four
ELSEIF(JYEAR.EQ.4.AND.JQUAR.EQ.1) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.4.AND.JQUAR.EQ.2) THEN
   CLOVER=6.+0.22*GPROP
ELSEIF(JYEAR.EQ.4.AND.JQUAR.EQ.3) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.4.AND.JQUAR.EQ.4) THEN
   CLOVER=12.+0.27*GPROP
C year five
ELSEIF(JYEAR.EQ.5.AND.JQUAR.EQ.1) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.5.AND.JQUAR.EQ.2) THEN
   CLOVER=6.+0.22*GPROP
ELSEIF(JYEAR.EQ.5.AND.JQUAR.EQ.3) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.5.AND.JQUAR.EQ.4) THEN
   CLOVER=12.+0.27*GPROP
C year six
ELSEIF(JYEAR.EQ.6.AND.JQUAR.EQ.1) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.6.AND.JQUAR.EQ.2) THEN
   CLOVER=6.+0.22*GPROP
ELSEIF(JYEAR.EQ.6.AND.JQUAR.EQ.3) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.6.AND.JQUAR.EQ.4) THEN
   CLOVER=12.+0.27*GPROP
C year seven
ELSEIF(JYEAR.EQ.7.AND.JQUAR.EQ.1) THEN
   CLOVER=10.+0.25*GPROP
ELSEIF(JYEAR.EQ.7.AND.JQUAR.EQ.2) THEN
   CLOVER=6.+0.22*GPROP
ELSE
   CONTINUE ENDIF
ENDIF
RETURN
END
C this subroutine sorts out the data arrays for the clover
C decline

SUBROUTINE CLOV2(JQUAR,C,D,PERC,E,F)
DIMENSION C(4),D(4),E(4),F(4),DEC(4)
C calc the values for c & d arrays depending on what
C quarter the calc came from the gorse section
IF(JQUAR.EQ.1)THEN
   DO I=1,4
      CC(I)=C(I)
      DD(I)=D(I)
   ENDDO
ELSEIF(JQUAR.EQ.2)THEN
   DO I=1,3
      CC(I)=C(I+1)
      DD(I)=D(I+1)
   ENDDO
   CC(4)=C(1)
   DD(4)=D(1)
ELSEIF(JQUAR.EQ.3)THEN
   DO I=1,2
      CC(I)=C(I+2)
      DD(I)=D(I+2)
      CC(I+2)=C(I)
      DD(I+2)=D(I)
   ENDDO
ELSE
   JQUAR must equal 4
   DO I=1,3
      CC(I+1)=C(I)
      DD(I+1)=D(I)
   ENDDO
   CC(1)=C(4)
   DD(1)=D(4)
ENDIF
C adjustment begins
C
calc the difference between all goats and no goats
DO I=1,4
   DIF(I)=DD(I)-CC(I)
ENDDO
C mult difference by appropriate % decrease
DO I=1,4
   DEC(I)=DIF(I)*PERC(I)
ENDDO
C set new coordinates for F array
DO I=1,4
   F(I)=DEC(I)+CC(I)
ENDDO
C set E array coordinates
DO I=1,4
   E(I)=CC(I)
ENDDO
C return to goats
RETURN
END
C this subroutine allocates clover % during clover decline
SUBROUTINE CLOV3(KOUNT,E,F,GPROP2,CLOVER)
DIMENSION E(4),F(4)
GPROP=GPROP2/100.
C calc the difference of clover %
DIFF=F(KOUNT)-E(KOUNT)
C new clover % is
CLOVER=(DIFF*GPROP)+E(KOUNT)
C return to goats
RETURN
END

C this subroutine allocates clover % given we are in the
C latter phase of the development
SUBROUTINE CLOV4(JQUAR,CLOVER)
IF(JQUAR.EQ.1)THEN
CLOVER=10.
ELSEIF(JQUAR.EQ.2)THEN
CLOVER=6.
ELSEIF(JQUAR.EQ.3)THEN
CLOVER=10.
ELSE
JQUAR must be 4
CLOVER=12.
ENDIF
C return to goats
RETURN
END

C this subroutine calculates sheep feed
SUBROUTINE SHFD(GPROP,SPRATOR,PAST,JQUAR,CLOVER,
*SHE,SHCLV,SHFDHD)
DIMENSION PAST(4)
C if goats make up all grazing then no sheep feed
C (this prevents division by zero)
IF(GPROP.EQ.100.)THEN
SHFDHD=0.
SHCLV=0.
GOTO 10
ENDIF
C set GPROP & CLOVER into correct proportions
GPROP=GPROP/100.
CLOVER=CLOVER/100.
C determine relevant areas of the 'S'square
A=(1-GPROP)*(1-SPRATOR)
B=GPROP*SPRATOR
C=(1-GPROP)*SPRATOR
C determine sheep proportion of the feed
SHPROP=(A+C)/(A+B+C)
C determine clover proportion in sheep diet
SHFEED=SHPROP*PAST(JQUAR)
CLOVERDM=PAST(JQUAR)*CLOVER
SHCLV=(CLOVERDM/SHFEED)*100.
C if clover greater than D.M. available to sheep
C SHCLV=100%
IF(SHCLV.GT.100.)THEN
SHCLV=100.
ENDIF
C determine feed available per head (sheep)
SHFDHD=SHFEED/SHE
C reset GPROP & CLOVER proportions
GPROP=GPROP*100.
CLOVER=CLOVER*100.
C return to goats
10 CONTINUE
RETURN
END
A program listing of the model used to simulate both the goat/sheep and chemical methods for gorse control. This program is written in FORTRAN 77 programming language.

**Programs:**
- MAIN.FOR
- GOATS.FOR
- GORSE.FOR
- WOOLLB.FOR
- GCALC.FOR
- SHEEP.R.FOR
- SHEEP.C.FOR
- CHEM.FOR
- IRRNpv.FOR
C This is the main program that drives the simulation

PROGRAM MAIN
CHARACTER *4 COMMAND
CHARACTER *4 DENSITY
CHARACTER *60 COMMENT
OPEN(UNIT=1, NAME='DAT.DAT', STATUS='OLD',
*ORGANIZATION='RELATIVE', ACCESS='DIRECT',
*RECL=100, FORM='FORMATTED')
READ(UNIT=1,FMT=110,REC=1)COMMAND,DENSITY,COMMENT,GRATE
READ(UNIT=1,FMT=120,REC=5)NCHOICE,MYEAR

110 FORMAT(2A4,2A60,F5.0)
120 FORMAT(2I3)

IF(COMMAND.EQ.'GOAT')THEN
 CALL GOATS(DENSITY,COMMENT,GRATE)
ELSEIF(COMMAND.EQ.'CHEM')THEN

C this section is for chemical
 CALL CHEM(COMMENT,MYEAR)
ELSE
 TYPE '*', 'THERE IS A MISTAKE SOMEWHERE !'
ENDIF
CLOSE(UNIT=1,DISPOSE='SAVE')
STOP
END
this subroutine drives the goat option

```plaintext
SUBROUTINE GOATS(DENSITY,GOAT,GRATE)

DIMENSION A(8,13),B(8,13),GOAT(10),SHEEP(10),SHFEED(8)
DIMENSION PAST(4),C(4),D(4),PERC(4),E(4),F(4),
DIMENSION PERLB(10),GOAT2(10),SHEEP2(10),WOOLKG2(10)
DIMENSION PERLB2(10),WOOLKG(10)
CHARACTER *60 COMMENT
CHARACTER *4 DENSITY
INTEGER JYEAR,JQUART,MCOUNT,KOUNT,LQUAR,IYEAR,IRATE
INTEGER LYEAR,KQ"UAR
REAL KID,KIQ,LPID,LAMB

READ(UNIT=I,FMT=150,REC=32)PAST
C determine which density of gorse is used
IF(DENSITY.EQ.'LOW')THEN
C read the gorse % cover data
DO J=1,13
   READ(UNIT=I,FMT=140,REC=J+5)(A(I,J),I=1,8)
ENDDO
DO J=1,13
   READ(UNIT=I,FMT=140,REC=J+18)(B(I,J),I=1,8)
ENDDO
C read more records
READ(UNIT=I,FMT=150,REC=33)C
READ(UNIT=I,FMT=150,REC=34)D
READ(UNIT=I,FMT=160,REC=35)PERC
C set the proportion of S.U. that are goats
GPOP=(GRATE*0.5)/9.*100.
GPOP2=GPOP
GRATE2=GRATE

C **********************
C * Set the first year *
C **********************

JYEAR=1
C set costings for burn and buying goats
GOAT(JYEAR)=GRATE
SHEEP(JYEAR)=(9.0-(GRATE*0.5))/1.0
BURN=100.
C this counter counts the quarters for gorse and clover
MCOUNT=-1
C set counters for print subroutine,IRATE for change in
c goat rate and LYEAR for change in years
IRATE=1
LYEAR=2

C *******************************************************
C * Commence the second year where goats begin grazing gorse *
C *******************************************************

DO JYEAR =2,6
   GOAT(JYEAR)=GRATE
   SHEEP(JYEAR)=(9.0-(GRATE*0.5))/1.0
   SHE=SHEEP(JYEAR)
C determine sheep production parameters
CALL WOOLLB(JYEAR,GPROP2,WOOLKG,PERLB)
C commence quarterly calc.
```
DO JQUAR=1,4
MOUNT=MOUNT+1
C calculate gorse % cover
CALL GORSE(JYEAR,JQUAR,MCOUNT,A,B,GPROP,GORCOV)
C check decision rule for gorse
IF(GORCOV.EQ.0.) GOTO 10
C calculate % clover in pasture
CALL CLOVI(JYEAR,JQUAR,CLOVER,GPROP)
C calculate the 'S' factor
THIST=0.
SFACOR=1.03-0.0091*GORCOV-0.0075*CLOVER
*-0.0037*THIST
C calculate the proportion of pasture available per sheep
CALL SHFD(GPROP, SFACOR, PAST, JQUAR, CLOVER, SHEE, *SHCLOV, SHFDHD)
C
C *******************************************************
C * no more gorse to be allowed for next stage *
C *******************************************************
C
C set the necessary parameters
10 IQUAR=JQUAR
GPROP2=GPROP
GRATE=2.
GOAT(JYEAR)=GRATE
SHEEP(JYEAR)=(9.0-(GRATE*0.5))/1.0
GPROP=((GRATE*0.5)/9.)*100.
SHEEP(JYEAR)=2
KOUNT=0
C determine sheep production parameters
CALL WOOLLB(JYEAR,GPROP2,WOOLKG,PERLB)
C calc clover decline for next two years
CALL CLOV2(IQUAR,C,D,PERC,E,F)
C commence the time step
DO KQUAR=IQUAR,IQUAR+3
C set correct JQUAR
JQUAR=KQUAR
IF(KQUAR.GT.4)THEN
JQUAR=KQUAR-4
ENDIF
C set KOUNT each quarter
KOUNT=KOUNT+1
C calc the % clover
CALL CLOV3(KOUNT,E,F,GPROP2,CLOVER)
C calc the 'S' factor
THIST=0.
SFACOR=1.03-0.0091*GORCOV-0.0075*CLOVER
*-0.0037*THIST
C calc feed & clover available for sheep
CALL SHFD(GPROP, SFACOR, PAST, JQUAR, CLOVER, SHEE, *SHCLOV, SHFDHD)
C test if the run has reached the end of the year
IF(JQUAR.EQ.4)THEN
C set the yearly calc in motion
GOAT(JYEAR)=GRATE
SHEEP(JYEAR)=(9.0-(GRATE*0.5))/1.0
C determine sheep production parameters
CALL WOOLLB(JYEAR,GPROP2,WOOLKG,PERLB)
JYEAR=JYEAR+1
ENDIF
C set IYEAR so we can determine what year we are in
IYEAR=JYEAR
C determine what quarter we are in
IF(JQUAR.EQ.1)THEN
    LQUAR=2
ELSEIF(JQUAR.EQ.2)THEN
    LQUAR=3
ELSEIF(JQUAR.EQ.3)THEN
    LQUAR=4
ELSE
    JQUAR must be 4 so go onto the next year
    GOTO 30
ENDIF
C finish of the year
DO JQUAR=LQUAR,4
C calc % clover
CALL CLOV4(JQUAR,CLOVER)
C calc 'S' factor
SFACTOR=1.03-0.0091*GORCOV-0.0075*CLOVER
* -0.0037*THIST
C calculate the proportion of pasture available per sheep
CALL SHFD(GPROP,SFACTOR,PAST,JQUAR,CLOVER,SHE,
*SHCLOV,SHFDHD)
ENDDO
C calc this years economic parameters
GOAT(JYEAR)=GRATE
SHEEP(JYEAR)=(9.0-(GRATE*0.5))/1.0
C determine sheep production parameters
CALL WOOLB(JYEAR,GPROP2,WOOLKG,PERLB)
IYEAR=JYEAR+1
C test to see if all years have been calculated
30 IF(JYEAR.GT.6) GOTO 20
C
C **********************************************
* finish off the year if only part year done *
C **********************************************
C
C convert arrays to be passed on to GCALC so correct years
C are used for calc (sorry this is due to poor programming)
DO I=2,JYEAR
WOOLKG2(I-1)=WOOLKG(I)
PERLB2(I-1)=PERLB(I)
GOAT2(I-1)=GOAT(I)
SHEEP2(I-1)=SHEEP(I)

ENDDO
MYEAR=JYEAR-2
C calc the economic returns
  CALL GCALC(MYEAR,GOAT2,SHEEP2,WOOLKG2,PERLB2,COMMENT
  *GRATE2)
C **********************************************************
  ELSEIF (DENSITY .EQ. 'HIGH') THEN
    CONTINUE
  ELSE
    TYPE *, 'THERE IS A MISTAKE IN GOAT SUBROUTINE
    *GOATS !'
    ENDF
C go into the economic calculations
20  CONTINUE
RETURN
END
C this subroutine calculates the appropriate gorse % cover
SUBROUTINE GORSE(JYEAR, JQUAR, MCOUNT, A, B, GPROP, GORCOV)
  DIMENSION A(8, 13), B(8, 13)
C gorse cover is set for the start of the second year
  IF(JYEAR.EQ.2 .AND. JQUAR.EQ.1) THEN
    GORCOV=5.
    GOTO 10
  ENDIF
C due to one linear function being parallel to x-axis in 3rd C quarter
  IF(JYEAR.EQ.2 .AND. JQUAR.EQ.3 .AND. GPROP.GT.33.) THEN
    GORCOV=1.80
    GOTO 10
  ENDIF
C a linear relationship being parallel to x-axis in 8th C quarter requires this section
  IF(JYEAR.EQ.4 .AND. JQUAR.EQ.1 .AND. GPROP.GT.66.) THEN
    GORCOV=0.
    GOTO 10
  ENDIF
C no % gorse cover remains after the 9th quarter
  IF(JYEAR.EQ.4 .AND. JQUAR.EQ.2) THEN
    GORCOV=0.
    GOTO 10
  ENDIF
C Otherwise gorse is determined from the functions stored in C A & B matrix
C find the A & B coordinates
  DO J=1, 13
    IF(GPROP.LE.B(MCOUNT, J)) GOTO 20
  ENDDO
C calc. from appropriate function's straight line to determine C gorse cover
  20 SLOPE=(A(MCOUNT, J-1)-A(MCOUNT, J))/(B(MCOUNT, J-1)
      -B(MCOUNT, J))
    COR=A(MCOUNT, J)-(SLOPE*B(MCOUNT, J))
    GORCOV=COR+(SLOPE*GPROP)
C continue if first gorse cover calc.
  10 CONTINUE
  RETURN
END
C this subroutine calculates the sheep production parameters
C as clover % in pasture changes through development
SUBROUTINE WOOLB(JYEAR,GPROP2,WOOLKG,PERLB)
DIMENSION WOOLKG(10),PERLB(10)
C *******************************************************
C * determine kg wool per ewe & lambing percentage *
C *******************************************************
C C determine year 1 wool production & lambing % per ewe
IF(JYEAR.EQ.2)THEN
WOOLKG(JYEAR)=4.50
PERLB(JYEAR)=90.0
ENDIF
C determine year 2
IF(JYEAR.EQ.3)THEN
IF(GPROP2.LE.33.334)THEN
  WOOLKG(JYEAR)=4.50
  PERLB(JYEAR)=90.0
  GOTO 10
ENDIF
IF(GPROP2.GT.66.0)THEN
  WOOLKG(JYEAR)=4.84
  PERLB(JYEAR)=95.6
  GOTO 10
ENDIF
WOOLKG(JYEAR)=4.16+(0.0103*GPROP2)
PERLB(JYEAR)=84.40+(0.1697*GPROP2)
ENDIF
C determine year 3
IF(JYEAR.EQ.4)THEN
IF(GPROP2.LE.33.334)THEN
  WOOLKG(JYEAR)=4.5
  PERLB(JYEAR)=90.
  GOTO 10
ENDIF
IF(GPROP2.GT.66.0)THEN
  WOOLKG(JYEAR)=4.67
  PERLB(JYEAR)=92.6
  GOTO 10
ENDIF
WOOLKG(JYEAR)=4.33+(0.0052*GPROP2)
PERLB(JYEAR)=87.4+(0.07879*GPROP2)
ENDIF
C determine year 4
IF(JYEAR.GT.4)THEN
WOOLKG(JYEAR)=4.50
PERLB(JYEAR)=90.
ENDIF
10 CONTINUE
C return to goats
RETURN
END
C this subroutine calc the economics of goats
C then prints results on a file and returns to GOAT
SUBROUTINE G CALC(JYEAR,GOAT,SHEEP,WOOLKG,PERLB,
  *COMMENT GRATE)
  CHARACTER *60 COMMENT
  CHARACTER *42 TITLE(29)
  DIMENSION TGOAT(0:10),TSHEEP(0:10),GOAT(10)
  DIMENSION GCAP11(0:10),GCAP12(0:10),TCAP(0:10)
  DIMENSION GRET11(0:10),TRET(0:10),SRET(0:10)
  DIMENSION SCOST(0:10),TCOST(0:10),APROF(0:10)
  DIMENSION GCAP22(0:10),GCAP1(0:10),GRE T21(0:10)
  DIMENSION GRET22(0:10),H(0:10),COST(0:10)
  DIMENSION SHEEP(10),SCAP(0:10),GOCOST(0:10)
  DIMENSION CP R O F(0:10),PERLB(10),WOOLKG(10)
  REAL NPV,IRR,KIDM,KIDX,KIDSC,LAMB

100 FORMAT(4F6.2,F7.2,3F6.2)
110 FORMAT(4F6.2)
120 FORMAT(I3)
130 FORMAT(8X,60)
C open results file
OPEN(UNIT=3,NAME='RES.DAT',STATUS='NEW')
READ(UNIT=1,FMT=100,REC=2)KIDM,KIDX,KIDSC,FERAL
  ,ANGB,CASHM,WOLG,XANG
READ(UNIT=1,FMT=110,REC=3)WOOL,LAMB,EWE,SVC
READ(UNIT=1,FMT=120,REC=5)NCHOICE
READ(UNIT=1,FMT=130,REC=1)COMMENT
C calc total stock used
DO I=1,JYEAR
  TGOAT(I)=GOAT(I)*30.,
  TSHEEP(I)=SHEEP(I)*30.,
ENDDO
TGOAT(0)=TGOAT(1)
TSHEEP(0)=TSHEEP(1)
C convert total goat & sheep figures to whole numbers
DO I=0,JYEAR
  TSHEEP(I)=ANINT(TSHEEP(I))
  TGOAT(I)=ANINT(TGOAT(I))
ENDDO
C set capital costs for fencing and burning
FENC=1144.
BURN=100.
TOPDRESS=4592.

C ***********************************************
C * calculate for 'DRY FERAL METHERS AND DOES' *
C ***********************************************
C IF(NCHOICE.EQ.1)THEN
C DETERMINE CAPITAL REQUIREMENTS
C goat capital
  GCAP11(0)=TGOAT(0)*FERAL
C calc replacements needed for deaths
  DO I=1,JYEAR
     GCAP11(I)=(TGOAT(I)*0.1)*FERAL
  ENDDO
C calc goat sales once gorse is gone
  DO I=1,JYEAR
     IF(TGOAT(I).NE.TGOAT(I-1))THEN
        GCAP21(I)=(TGOAT(I-1)-TGOAT(I))
   **FERAL
ENDIF
ENDDO
C calc sheep capital
CALL SHEEP(TSHEEP,JYEAR,EWE,SCAP)
C calc total capital
DO I=0,JYEAR
   TCAP(I)=GCAP11(I)+SCAP(I)-GCAP21(I)
   IF(I.EQ.0)THEN
      TCAP(0)=FENC+TCAP(0)
   ENDIF
ENDDO
C DETERMINE RETURNS
C calc return from cashmere
DO I=1,JYEAR
   GRET11(I)=TGOAT(I)*0.2*0.5*CASHM
ENDDO
C calc sheep return
CALL SHEEP(TSHEEP,JYEAR,SRET,WOOLK,PERLB,*,WOOL,LAMB)
C calc total return
DO I=1,JYEAR
   TRET(I)=GRET11(I)+SRET(I)
ENDDO
C DETERMINE VARIABLE COSTS
C calc variable costs for goats (husbandry, 2* shearing & cashmere trans.)
DO I=1,JYEAR
   GCOST(I)=(TGOAT(I)*1.44)+
   *(TGOAT(I)*2.*1.05)+(TGOAT(I)*0.2*0.5*1.0)+
   *(TGOAT(I)*1.*0.5)
ENDDO
GVCOST=GCOST(I)/TGOAT(I)
C calc variable costs for sheep
DO I=1,JYEAR
   SVC(I)=TSHEEP(I)*SVC
ENDDO
C calc total variable costs
DO I=1,JYEAR
   TCOST(I)=GCOST(I)+SCOST(I)
ENDDO
TCOST(0)=TOPRESS+BURN
C DETERMINE PROFITABILITY
C calc annual and cumulative profit
DO I=0,JYEAR
   APROF(I)=TRET(I)-TCAP(I)-TCOST(I)
   IF(I.EQ.0)THEN
      CPROF(I)=APROF(I)
   ELSE
      CPROF(I)=APROF(I)+CPROF(I-1)
   ENDIF
ENDDO
C calc the COST array for benefit cost ratio
DO I=0,JYEAR
   COST(I)=TCAP(I)+TCOST(I)
ENDDO
C check to see when steady state is reached and alter C JYEAR so that only one year of steady state is calculated
DO I=3,JYEAR
   IF(APROF(I).EQ.APROF(I-1))THEN
      MYEAR=JYEAR-1
      GOTO 300
   ELSE
      MYEAR=JYEAR-1
      GOTO 300
   ENDIF
ENDDO

167.
MYEAR=JYEAR
ENDDO

JYEAR=MYEAR
C calc IRR & NPV
CALL IRRNPV(APROF,COST,TRET,JYEAR,IRR,NPV,BC)

C **************************************************
C * calculate for 'FIRST AND SECOND CROSS WETHERS' *
C **************************************************
C
ELSEIF(NCHOICE.EQ.2)THEN
C DETERMINE CAPITAL REQUIREMENTS
C goat capital
GCAP11(0)=TGOAT(0)*XANG
C calc replacements needed for deaths
DO I=1,JYEAR
  GCAP11(I)=(TGOAT(I)*0.1)*XANG
ENDDO
C calc goat sales once gorse is gone
DO I=1,JYEAR
  IF(TGOAT(I).NE.TGOAT(I-1))THEN
    GCAP21(I)=(TGOAT(I-1)-TGOAT(I))*XANG
  ENDIF
ENDDO
C calc sheep capital
CALL SHEEPC(TSHEEP,JYEAR,EWE,SCAP)
C calc total capital
DO I=0,JYEAR
  TCAP(I)=GCAP11(I)+SCAP(I)-GCAP21(I)
  IF(I.EQ.0)THEN
    TCAP(0)=FENC+TCAP(0)
  ENDIF
ENDDO
C DETERMINE RETURNS
C calc return from cashgora
DO I=1,JYEAR
  GRET11(I)=TGOAT(I)*1.0*CASHG
ENDDO
C calc sheep return
CALL SHEEPR(TSHEEP,JYEAR,SRET,WoolKG,PERLB *
  *,WoolLAM)
  SRET=RET(5)/TSHEEP(5)
C calc total return
DO I=1,JYEAR
  TRET(I)=GRET11(I)+SRET(I)
ENDDO
C DETERMINE VARIABLE COSTS
C calc variable costs for goats (husbandry, shearing
C & cashgora trans.)
DO I=1,JYEAR
  GCOST(I)=(TGOAT(I)*1.44)+(TGOAT(I)*1.05)
  + (TGOAT(I)*0.1*0.5)+(TGOAT(I)*1.0)
ENDDO
  VCOST(GCOST(I)/TGOAT(I)
C calc variable costs for sheep
DO I=1,JYEAR
  SCOST(I)=TSHEEP(I)*SVC
ENDDO
C calc total variable costs
DO I=1,JYEAR
  TCOST(I)=GCOST(I)+SCOST(I)
ENDDO
TCOST(0)=TOPRESS+BURN

C DETERMINE PROFITABILITY
C calc annual and cumulative profit
DO I=0,JYEAR
   APROF(I)=TRET(I)-TCAP(I)-TCOST(I)
   IF(I.EQ.0)THEN
      CPROF(I)=APROF(I)
   ELSE
      CPROF(I)=APROF(I)+CPROF(I-1)
   ENDF
ENDDO
C calc the COST array for benefit cost ratio
DO I=0,JYEAR
   COST(I)=TCAP(I)+TCOST(I)
ENDDO
C check to see when steady state is reached and alter
C JYEAR so that only one year of steady state is
C calculated
DO I=3,JYEAR
   IF(APROF(I).EQ.APROF(I-1))THEN
      MYEAR=JYEAR-1
      GOTO 310
   ELSE
      MYEAR=JYEAR
   ENDF
ENDDO
310 JYEAR=MYEAR
C calc IRR & NPV
CALL IRRNPV(APROF,COST,TRET,JYEAR,IRR,
             *NPV,BC)
C
C *******************************************************
C * calculate for 'FERAL DOES WITH ALL PROGENY SOLD *
C * AS MEAT' *
C *******************************************************
ELSEIF(NCHOICE.EQ.3)THEN
C DETERMINE CAPITAL REQUIREMENTS
C goat capital (& feral bucks)
   GCAPI1(O)=(TGOAT(O)*FERAL)+
              *(TGOAT(O)*0.025*FERAL)
C calc goat sales once gorse is gone
DO I=1,JYEAR
   IF(TGOAT(I).NE.TGOAT(I-1))THEN
      GCAP21(I)=(TGOAT(I-1)-TGOAT(I))*
                 FERAL+(TGOAT(I-1)-TGOAT(I))*0.025*FERAL
   ENDIF
ENDDO
C calc sheep capital
CALL SHEEP(TSHEEP,JYEAR,EWE,SCAP)
C calc total capital
DO I=0,JYEAR
   TCAP(I)=GCAPI1(I)+SCAP(I)-GCAP21(I)
   IF(I.EQ.0)THEN
      TCAP(0)=FENC+TCAP(0)
   ENDIF
ENDDO
C DETERMINE RETURNS
C calc return from goat progeny (progeny - replacements)
DO I=1,JYEAR
   GRET21(I)=(TGOAT(I)*0.8)-(TGOAT(I)*0.376)
   )*KIDM
ENDDO
CALL SHEEP(SHEEP,JYEAR,SRET,WOOLKG,PERLB
*,WOOL,LAMB)

SHEEPRT=SRET(5)/TSHEEP(5)

C calc total return
DO I=1,JYEAR
TRET(I)=GRET21(I)+SRET(I)
ENDDO

C DETERMINE VARIABLE COSTS

C calc variable costs for goats & kids (husbandry & kid transport)
DO I=1,JYEAR
GCOST(I)=(TGOAT(I)*1.44)+((TGOAT(I)*0.80)**0.33)+(TGOAT(I)*0.8)-(TGOAT(I)*0.376)*0.50
ENDDO

GVCOST=GCOST(I)/TGOAT(I)

C calc variable costs for sheep
DO I=1,JYEAR
SCOST(I)=TSHEEP(I)*SVC
ENDDO

C calc total variable costs
DO I=1,JYEAR
TCOST(I)=GCOST(I)+SCOST(I)
ENDDO

TCOST(0)=TOPDRESS+BURN

C DETERMINE PROFITABILITY

C calc annual and cumulative profit
DO I=0,JYEAR
APROF(I)=TRET(I)-TCAP(I)-TCOST(I)
IF(I.EQ.0)THEN
CPROF(I)=APROF(I)
ELSE
CPROF(I)=APROF(I)+CPROF(I-1)
ENDIF
ENDDO

C calc the COST array for benefit cost ratio
DO I=0,JYEAR
COST(I)=TCAP(I)+TCOST(I)
ENDDO

C check to see when steady state is reached and alter C JYEAR so that only one year of steady state is C calculated
DO I=3,JYEAR
IF(APROF(I).EQ.APROF(I-1))THEN
MYEAR=JYEAR-1
GOTO 320
ELSE
MYEAR=JYEAR
ENDIF
ENDDO

320 MYEAR=MYEAR

C calc IRR & NPV
CALL IRRNPV(APROF,COST,TRET,JYEAR,IRR,NPV,BC)

C ******************************************************
C * calculate for 'FERAL DOES CROSSED TO ANGORA BUCKS' *
C * female kids sold as 1st cross & wether kids as *
C * scrub control *
C ******************************************************

C ELSE
C must be choice 4

C DETERMINE CAPITAL REQUIREMENTS
C goat capital

\[ GCAP_{11}(0) = TGOAT(0) \times FERAL \]

C convert angora buck requirement to whole number

\[ GCAP_{12}(0) = TGOAT(0) \times 0.025 \]

\[ GCAP_{12}(0) = ANINT(GCAP_{12}(0)) \]

\[ GCAP_{12}(0) = GCAP_{12}(0) \times ANGB \]

C calc replacement bucks & does

DO I=1,JYEAR

\[ GCAP_{11}(I) = TGOAT(I) \times 0.376 \times FERAL \]

\[ GCAP_{12}(I) = ABS(TGOAT(I) \times 0.025 \times 0.2) \times ANGB \]

ENDDO

C calc goat sales once gorse is gone

DO I=1,JYEAR

IF(TGOAT(I) .NE. TGOAT(I-1)) THEN

\[ GCAP_{22}(I) = (TGOAT(I-1) - TGOAT(I)) \times 0.025 \]

\[ GCAP_{22}(I) = ANINT(GCAP_{22}(I)) \]

\[ GCAP_{22}(I) = GCAP_{22}(I) \times ANGB \]

ENDIF

ENDDO

C calc sheep capital

CALL SHEEPCT(SHEEP,JYEAR,EWE,SCAP)

C calc total capital

DO I=0,JYEAR

\[ TCAP(I) = GCAP_{11}(I) + GCAP_{12}(I) + SCAP(I) - GCAP_{21}(I) - GCAP_{22}(I) \]

IF(I .EQ. 0) THEN

\[ TCAP(0) = FENC + TCAP(0) \]

ENDIF

ENDDO

C DETERMINE RETURNS

C calc return from goat progeny (1st X does & scub C wethers)

DO I=1,JYEAR

\[ GRET_{21}(I) = (TGOAT(I) \times 0.80 \times 0.5) \times KIDSC \]

\[ GRET_{22}(I) = (TGOAT(I) \times 0.80 \times 0.5) \times KIDX \]

ENDDO

C calc sheep return

CALL SHEEPR(SHEEP,JYEAR,SRET,WOOLKG,PERLB

*,WOOL,LAMB)

\[ SHEEPRET = SRET(5) / TSHEEP(5) \]

C calc total return

DO I=1,JYEAR

\[ TRET(I) = GRET_{21}(I) + GRET_{22}(I) + SRET(I) \]

ENDDO

C DETERMINE VARIABLE COSTS

C calc variable costs for goats & kids (husbandry & C transport for replacement does)

DO I=1,JYEAR

\[ GCOST(I) = (TGOAT(I) \times 1.44) + ((TGOAT(I) \times 0.8 \times 0.33) + (TGOAT(I) \times 0.376 \times 0.5)) \]

ENDDO

\[ GVCOSt = GCOST(I) / TGOAT(I) \]

C calc variable costs for sheep

DO I=1,JYEAR

\[ SCOST(I) = TSHEEP(I) \times SVC \]

ENDDO

C calc total variable costs
DO I=1, JYEAR
TCOST(I)=GCOST(I)+SCOST(I)
ENDDO
TCOST(0)=TOPDRESS+BURN
C DETERMINE PROFITABILITY
C calc annual and cumulative profit
DO I=0, JYEAR
APROF(I)=TRET(I)-TCAP(I)-TCOST(I)
IF(I.EQ.0)THEN
  CPROF(I)=APROF(I)
ELSE
  CPROF(I)=APROF(I)+CPROF(I-1)
ENDIF
ENDDO
C calc the COST array for benefit cost ratio
DO I=0, JYEAR
COST(I)=TCAP(I)+TCOST(I)
ENDDO
C check to see when steady state is reached and alter C JYEAR so that only one year of steady state is C calculated
DO I=3, JYEAR
IF(APROF(I),EQ.,APROF(I-1))THEN
  MYEAR=JYEAR-1
GOTO 330
ELSE
  MYEAR=JYEAR
ENDIF
ENDDO
330  JYEAR=MYEAR
C calc IRR & NPV
CALL IRRNPV(APROF,COST,TRET,JYEAR,IRR *,NPV,BC)
ENDIF
C ********************************
C * *
C * PRINT ONTO THE RESULTS FILE *
C *
C ********************************
DATA TITLE/
*YEARS
* no. of goats (initial goats =
* no. of sheep
* goats : purchase - feral does & wths. ($
* goats : purchase - 1st & 2nd X wths. ($$
* goats : purchase - feral does
* : angora bucks
* : sales - feral (does & wths.) ($$
* : sales - 1st & 2nd X wethers ($$$
* : sales - feral does
* : angora bucks
* fencing : one hot wire
* burning
* sheep : purchases (ewes) ($$
* TOTAL CAPITAL REQUIREMENTS
* goats : progeny - scrub control ($$
* goats : progeny - meat ($$$
* goats : progeny - lst. cross does
* : scrub wths.
* goats : fibre - cashmere ($$$
* goats : fibre - cashgora ($$
* sheep : gross return ($$
* 'TOTAL RETURN
 * goats
 * sheep
 * 'TOTAL COSTS
 * 'ANNUAL PROFIT
 * 'CUMULATIVE PROFIT
 * topdressing

C START PRINTING THE TABLE

WRITE(3,16)
C put the comment on top
WRITE(3,1)COMMENT
1 FORMAT(10X,A60)
C write out land area
WRITE(3,17)
17 FORMAT(1X,/,'(Land area = 30 ha)'/)
C set up year array
DO I=0,10
 H(I)=I
ENDDO
C put on the years
WRITE(3,2)TITLE(1),(H(I),I=0,JYEAR)
2 FORMAT(1X,A52,'(H(I),I=0,JYEAR)
C draw a line
WRITE(3,3)
3 FORMAT(1X,52('-'),JYEAR+1>(8('-')))  
C write up physical data
WRITE(3,4)
4 FORMAT(1X,PHYSICAL DATA')
WRITE(3,20)TITLE(2),GRATE,(TGOAT(I),I=0,JYEAR)
20 FORMAT(1X,A42,F6.2,'/ha'),<JYEAR+1>F8.0)
5 FORMAT(1X,A42,10X,<JYEAR+1>F8.0)
WRITE(3,5)TITLE(3),GRATE,(TSHEEP(I),I=0,JYEAR)
WRITE(3,21)WOLKG(I),I=1,JYEAR)
5 FORMAT(1X/,3X,'changes in animal production: wool ')
* (kg/ewe) 0.0',<JYEAR>F8.2)
WRITE(3,22)PERLB(I),I=1,JYEAR)
22 FORMAT(X,0.0',<JYEAR>F8.1)
WRITE(3,3)
C C write down the capital requirement
WRITE(3,6)
6 FORMAT(1X,CAPITAL REQUIREMENTS (no land included)')
IF(NCHOICE.EQ.1)THEN
 WRITE(3,7)TITLE(4),FERAL,(GCAP11(I),I=0,JYEAR)
7 FORMAT(1X,A42,F6.2,'/ha'),<JYEAR+1>F8.0)
 ELSE IF(NCHOICE.EQ.2)THEN
 WRITE(3,7)TITLE(5),XANG,(GCAP11(I),I=0,JYEAR)
 ELSE IF(NCHOICE.EQ.3)THEN
 WRITE(3,7)TITLE(6),FERAL,(GCAP11(I),I=0,JYEAR)
 ELSE
 WRITE(3,7)TITLE(7),ANGB,(GCAP12(I),I=0,JYEAR)
 WRITE(3,7)TITLE(8),FERAL,(GCAP21(I),I=0,JYEAR)
 ELSE
 WRITE(3,7)TITLE(9),ANGB,(GCAP22(I),I=0,JYEAR)
 ENDIF
WRITE(3,7)TITLE(14),EWE,(SCAP(I),I=0,JYEAR)
WRITE (3,8) TITLE (12), FENC
WRITE (3,3)
WRITE (3,5) TITLE (15), (TCAP(I), I=0, JYEAR)
WRITE (3,3)

C write down returns

WRITE (3,9)
FORMAT (IX, 'RETURNS')
IF (NCHOICE.EQ.1) THEN
  WRITE (3,11) TITLE (20), CASHM, (GRET11(I), I=0, JYEAR)
  WRITE (3,11) TITLE (15), CASHM, (GRET11(I), I=0, JYEAR)
ELSEIF (NCHOICE.EQ.2) THEN
  WRITE (3,11) TITLE (21), CASHG, (GRET11(I), I=0, JYEAR)
ELSEIF (NCHOICE.EQ.3) THEN
  WRITE (3,7) TITLE (17), KIDM, (GRET21(I), I=0, JYEAR)
ELSE
  WRITE (3,7) TITLE (18), KIDX, (GRET22(I), I=0, JYEAR)
WRITE (3,7) TITLE (19), KIDS, (GRET21(I), I=0, JYEAR)
ENDIF
WRITE (3,23) WOOL, LAMB, (SRET(I), I=0, JYEAR)
FORMAT (IX, 'sheep:
  (wool $', F5.2, '/kg')
WRITE (3,3)
WRITE (3,5) TITLE (23), (TRET(I), I=0, JYEAR)
WRITE (3,3)

C write down costs

WRITE (3,13)
FORMAT (IX, 'VARIABLE COSTS')
WRITE (3,8) TITLE (13), BURN
WRITE (3,8) TITLE (29), TOPDRESS
WRITE (3,7) TITLE (24), (GCOST(I), I=0, JYEAR)
WRITE (3,7) TITLE (25), (SCOST(I), I=0, JYEAR)
WRITE (3,3)

C write down financial results

WRITE (3,5) TITLE (26), (TCOST(I), I=0, JYEAR)
WRITE (3,3)
WRITE (3,5) TITLE (27), (APROF(I), I=0, JYEAR)
WRITE (3,3)
WRITE (3,5) TITLE (28), (CPROF(I), I=0, JYEAR)
WRITE (3,3)
WRITE (3,14) IRR, NPV, BC
FORMAT (IX, /, IX, 'IRR =', F6.2, '%', 6X, 'NPV at 5% = $'
  *, F10.6X, 'Benefit Cost Ratio at 5% = ', F8.2)
CLOSE (UNIT=3, DISPOSE='SAVE')
RETURN
END
C this subroutine calc the revenue from sheep

SUBROUTINE SHEEPR(TSHEEP, JYEAR, SRET, WOOLKG, PERLB, 
* WOOL, LAMB)

REAL LAMB

DIMENSION TSHEEP(0:JYEAR), SRET(0:JYEAR)

DIMENSION PERLB(JYEAR), WOOLKG(JYEAR)

C calc sheep return stream

DO I=1, JYEAR

C calc the wool section of the gross revenue

WOOLRET=TSHEEP(I)*WOOLKG(I)*WOOL

C calc the return from lambs at the lambing percentage

RETLAMB=((TSHEEP(I)*(PERLB(I)/100.))

*(-(TSHEEP(I)*0.376))*LAMB

C calc total sheep return

SRET(I)=WOOLRET+RETLAMB

ENDDO

C return to GCALC

RETURN

END

C this subroutine calculates the capital requirements for sheep

SUBROUTINE SHEEPC(TSHEEP, JYEAR, EWE, SCAP)

DIMENSION TSHEEP(0:JYEAR), SCAP(0:JYEAR)

DO I=0, JYEAR

SCAP(I)=0.

ENDDO

SCAP(0)=TSHEEP(0)*EWE

DO I=1, JYEAR

IF(TSHEEP(I).NE.TSHEEP(I-1))THEN

SCAP(I)=(TSHEEP(I)-TSHEEP(I-1))*EWE

ENDIF

ENDDO

C return to GCALC

RETURN

END
C this subroutine simulates the chemical option

SUBROUTINE CHEM(COMMENT,MYEAR)
CHARACTER *60 COMMENT
CHARACTER *37 TITLE(14)
DIMENSION CPROP(10),SHEEP(11),SPRAY(0:11)
DIMENSION TCOST(0:11),APROF(0:11),CPROP(0:11)
DIMENSION SHEEP(0:11),ARRAY(0:11),SHVC(0:11)
DIMENSION COST(0:11),RET(0:11),CHPR(0:11)
DIMENSION H(0:11),CAP(0:11)
REAL LAMB,IRR,NPV
100 FORMAT(4F6.2)
110 FORMAT(3F6.2)
120 FORMAT(1OF6.2)
READ(UNIT=1,FMT=100,REC=3)WOOL,LAMB,EWE,SVC
READ(UNIT=1,FMT=110,REC=4)CHEMIC,HELIL,HELIH
READ(UNIT=1,FMT=120,REC=36)CPROP
OPEN(UNIT=3,NAME='RES.DAT',STATUS='NEW')

C set up the full sheep carrying potential of the land
SHEEP=9.0/1.0*30.
C set up the no of sheep carried throughout the development
C phase
DO I=1,MYEAR
  SHEEP(I)=CPROP(I)*SHEEP
  SHEEP(I-1)=SHEEP(I)
ENDDO SHEEP(MYEAR)=SHEEP(MYEAR)
SHEEP(MYEAR+1)=SHEEP(MYEAR)

C alter sheep arrays to whole numbers
DO I=1,MYEAR
  SHEEP(I)=ANINT(SHEEP(I))
  SHEEP(I-1)=ANINT(SHEEP(I))
ENDDO
DO I=0,MYEAR
  SHEEP(I)=ANINT(SHEEP(I))
  SHEEP(I-1)=ANINT(SHEEP(I))
ENDDO

C *****************************************
C * calc the year zero expences *
C *****************************************
CAP(0)=SHEEP(0)*EWE
TOPDRESS=4592.
BURN=100.
SPRAY(0)=5.*30.*CHEMIC
CHOPHEVY=HELIL*30.
TCOST(0)=TOPDRESS+BURN+SPRAY(0)+CHOPHEVY
APROF(0)=-(TCOST(0)+CAP(0))
CPROF(0)=APROF(0)

C *****************************************
C * calc remaining years *
C *****************************************
DO I=1,MYEAR
C calc the capital costs
  CAP(I)=(SHEEP(I)-SHEEP(I-1))*EWE
C calc the return
  WOOLET=SHEEP(I)*4.5*WOOL
  RETLAMB=((SHEEP(I)*0.90)-
  *(SHEEP(I)*0.376))*LAMB
  RET(I)=WOOLET+RETLAMB
C calc the costs
  SPRAY(I)=1.5*30.*CHEMIC
  CHOPR(I)=HELIL*30.
  SHVC(I)=SHEEP(I)*SVC
  TCOST(I)=SPRAY(I)+CHOPR(I)+SHVC(I)
calc annuity cashflow when only maintenance

spray is used

IF(I.GT.5)THEN
  SPRAY(I)=2.*9.*30.
  CHOPR(I)=0.
  SHVC(I)=SHEEP(I)*SVC
  TCOST(I)=SPRAY(I)+SHVC(I)
ENDIF

calc profit

APROF(I)=RET(I)-CAP(I)-TCOST(I)
CPROF(I)=APROF(I)+CPROF(I-1)

C set arrays for benefit cost calc
DO I=0,MYEAR
  COST(I)=CAP(I)+TCOST(I)
ENDO

calc IRR & NPV
CALL IRRNPV(APROF,COST,RET,MYEAR,IRR,NPV,BC)

****************************************************************
C print out the results
****************************************************************

DATA TITLE/ *'YEAR' *
  *'proportion of potential (%)', *
  *'no. of sheep', *
  *'sheep : purchase (eves)' ($) ' *
  *'sheep : gross return' ($) ' *
  *'burning', *
  *'topdressing', *
  *'chemical 2,4,5-T', *
  *'helicopter application - high vol. ('$'), *
  *'helicopter application - low vol. ('$'), *
  *'sheep : variable costs' ($), *
  *'TOTAL COSTS', *
  *'ANNUAL PROFITS', *
  *'CUMULATIVE PROFIT'/

C start the printing

WRITE(3,16)
16  FORMAT(Ix,//////////)

C put the comment on top
WRITE(3,1)COMMENT
1  FORMAT(10X,A60)

C write out the land area
WRITE(3,17)
17  FORMAT(1x,/,1x,'(Land area = 30 ha)',),/

C set up year array
DO I=0,MYEAR
  H(I)=I
ENDO

C put on the years
WRITE(3,2)TITLE(1),(H(I),I=0,MYEAR)
2  FORMAT(1x,A37,12X,'MYEAR+1'),F8.0)

C draw a line
WRITE(3,3)
3  FORMAT(1x,49(''),MYEAR+1),(8('-')))\n
C write up physical data
WRITE(3,4)
4  FORMAT(1X,'PHYSICAL DATA')

C organize the CPROP array for printing
DO I=1,MYEAR
  ARRAY(I)=CPROP(I)*100.

ENDDO
WRITE(3,5) TITLE(2),(ARRAY(I),I=1,MYEAR)
FORMAT(3X, A37, 9X, 0.0, <MYEAR+F8.1,
WRITE(3,2) TITLE(3),(SHEEP(I),I=0,MYEAR)
WRITE(3,3)
C
C write down capital requirements
C
WRITE(3,6)
FORMAT(3X, 'CAPITAL REQUIREMENTS')
WRITE(3,7)
FORMAT(3X, 'no land included')
WRITE(3,8) TITLE(4), EWE, (CAP(I),I=0,MYEAR)
FORMAT(3X, A37, P6.2, /hd), <MYEAR+1>F8.0)
WRITE(3,3)
C
C write down returns
C
WRITE(3,10)
FORMAT(3X, 'RETURNS')
WRITE(3,11) WOOL, LAMB, (RET(I),I=0,MYEAR)
*(lamb $', P6.2, '/hd'), <MYEAR+1>F8.0)
WRITE(3,3)
C
C write down costs
C
WRITE(3,12)
FORMAT(3X, 'VARIABLE COSTS')
WRITE(3,9) TITLE(6), BURN
FORMAT(3X, A37, 10X, P8.0)
WRITE(3,13) TITLE(7), TOPDRESS
WRITE(3,14) TITLE(8), CHEMIC, (SPRAY(I),I=0,MYEAR)
FORMAT(3X, A37, P6.2, /1), <MYEAR+1>F8.0)
WRITE(3,14) TITLE(9), HELIH, CHOPHEVY
FORMAT(3X, A37, P6.2, /ha'), F8.0)
WRITE(3,15) TITLE(10), HELIL, (CHOPR(I),I=0,MYEAR)
FORMAT(3X, A37, P6.2, /ha'), <MYEAR+1>F8.0)
WRITE(3,16) TITLE(11), SVC, (SHVC(I),I=0,MYEAR)
WRITE(3,3)
C
C write down profits
C
WRITE(3,12) TITLE(12), (TCOST(I),I=0,MYEAR)
WRITE(3,3)
WRITE(3,13) TITLE(13), (APROF(I),I=0,MYEAR)
WRITE(3,3)
WRITE(3,14) TITLE(14), (CROF(I),I=0,MYEAR)
WRITE(3,3)
WRITE(3,15) TITLE(15), IRR, NPV, BC
WRITE(1,10) /, IX, 'IRR = ', P6.2, ' %', 6X, 'NPV at 5% = ', F10.0, 6X, Benefit Cost Ratio at 5% = ', F8.2
C close res.dat file
CLOSE(UNIT=3, DISPOSE= 'SAVE')
RETURN
END
C this subroutine calc IRR & NPV
SUBROUTINE IRRNPV(APROF, COST, RET, JYEAR, IRR, NPV, BC)
DIMENSION APROF(0:11), DIS(0:11), COST(0:11), RET(0:11)
DIMENSION CT(0:11), B(0:10), BPROF(0:10), ACOST(0:10)
DIMENSION IRR(0:10)
REAL IRR, NPV
C set up new profit stream to allow for the steady state
C income to be calculated as perpetual annuity @ 5%. This
C array will not be printed in the development budget
DO I = 0, JYEAR
    BPROF(I) = APROF(I)
ENDDO
BPROF(JYEAR) = APROF(JYEAR) / 0.05
C :::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::
C commence calculation of IRR
RATE = 0.12
C set up a counter in case of non-convergence
KOUNT = 0
C initialise PV & DERIV
10 PV = 0,
DERIV = 0.
C add 1 to counter and if over 20 pull out
KOUNT = KOUNT + 1
IF(KOUNT .GT. 20) THEN
    WRITE(3, 100) RATE,
    FORMAT('PULLED OUT AT RATE = ', F8.2)
GOTO 200
ENDIF
C find alpha
ALPHA = 1./(1 + RATE)
C run round do loop to sum for PV and first DERIV
DO I = 0, JYEAR
    PV = PV + BPROF(I) * ALPHA ** I
    DERIV = DERIV + (-I) * BPROF(I) * ALPHA ** (I + 1)
ENDDO
C find new interest rate called RAT
RAT = RATE - PV / DERIV
C test if new rate has only changed a little
C if not then run round loop again with updated rate
IF(ABS(RAT - RATE) .GT. 0.0001) THEN
    RATE = RAT
GOTO 10
ENDIF
IRR = RATE * 100.
C calc NPV using 5% discount rate
200 NPV = 0.
DO I = 0, JYEAR
    NPV = NPV + (BPROF(I) / (1 + 0.05) ** I))
ENDDO
C alter the final cost and return of the steady state to
C allow for perpetual annuity at 5% and set up new array
C for B/C ratio
DO I = 0, JYEAR
    ACOST(I) = COST(I)
    ARET(I) = RET(I)
ENDDO
ACOST(JYEAR) = COST(JYEAR) / 0.05
ARET(JYEAR) = RET(JYEAR) / 0.05
C calc the benefit cost ratio using 5% discount rate
CST=0.
BEN=0.
DO I=0,JYEAR
   CST=CST+(COST(I)/((1+0.05)**I))
   BEN=BEN+(RET(I)/((1+0.05)**I))
ENDDO
BC=BEN/CST
C ...........................................................
   TYPE * 'IRR = 'IRR
   TYPE * 'NPV = 'NPV
C ...........................................................
C return to GCALC
RETURN
END
APPENDIX 12

PROGRAM LISTING OF THE INTERACTIVE PROGRAM
AND A PROGRAM TO CONSTRUCT THE INITIAL DATA FILE

The first program listing is of the interactive program developed for easy adjustment of economic and some physical variables stored in the main data file DAT.DAT. The second program creates the initial data file (DAT.DAT) that supplies the necessary data for the model. These programs are written in Fortran 77 programming language. Screen formatting library functions are also assessed by the interactive program.

PROGRAM: SET.FOR
INSET.FOR
C This program helps change data in the data file

PROGRAM SET
CHARACTER *10 NAM
CHARACTER *60 COMMENT, OLD COM
CHARACTER *4 COMMAND, DENSITY
CHARACTER *9 NN, NNN
CHARACTER *9 PROMPT
DIMENSION CPROP(10)
REAL KIDM, KIDX, KIDSC, LAMB
100 FORMAT (A20)
110 FORMAT (2A4, A60, F5.0)
120 FORMAT (4F6.2, F7.2, 3F6.2)
130 FORMAT (4F6.2)
140 FORMAT (3F6.2)
150 FORMAT (2I3)
180 FORMAT (10F6.3)

C ask for data file & comment for this file
ISTAT=LIB$PRASE_PAGE(1,1)
ISTAT=LIB$PUT_SCREEN('Which data file are you using ?', 8, 1)
ISTAT=LIB$PUT_SCREEN('What is the title comment ? <', 10, 1)
ISTAT=LIB$PUT_CURSOR(8, 33)
ISTAT=LIB$GET_SCREEN(NAM)
ISTAT=LIB$SET_CURSOR(10, 30)
ISTAT=LIB$GET_SCREEN(COMMENT)

C open the data file
OPEN (UNIT=1, NAME=NAM, STATUS='OLD', ORGANIZATION='RELATIVE',
ACCESS='DIRECT', RECL=100, FORM='FORMATTED')

C read the data file
READ(UNIT=1,FMT=110,REC=1) COMMAND, DENSITY
READ(UNIT=1,FMT=120,REC=2) KIDM, KIDX, KIDSC, FERAL
READ(UNIT=1,FMT=130,REC=3) WOOL, LAMB, EWE, SVC
READ(UNIT=1,FMT=140,REC=4) CHEM, HELLI, HELIH
READ(UNIT=1,FMT=150,REC=5) NCHOICE, MYEAR
READ(UNIT=1,FMT=180,REC=36) CPROP

C write the comment in the data file
WRITE(UNIT=1,FMT=110,REC=1) COMMAND, DENSITY, COMMENT

C clear the screen
200 ISTAT=LIB$PRASE_PAGE(1,1)

C set the main menu
ISTAT=LIB$PUT_SCREEN('Which aspect would you like to deal with ?', 3, 9)
ISTAT=LIB$PUT_SCREEN('1.- goats', 5, 15)
ISTAT=LIB$PUT_SCREEN('2.- the command for goat or chemical', 7, 15)
ISTAT=LIB$PUT_SCREEN('3.- sheep', 9, 15)
ISTAT=LIB$PUT_SCREEN('4.- chemicals', 11, 15)
ISTAT=LIB$PUT_SCREEN('5.- gorse', 13, 15)
ISTAT=LIB$PUT_SCREEN('6.- read current data file', 15, 15)
ISTAT=LIB$PUT_SCREEN('7.- end data alteration', 17, 15)

C accept the command from the terminal
ISTAT=LIB$PUT_SCREEN('Your choice :', 20, 5)
ISTAT=LIB$SET_CURSOR(20,19)
ISTAT=LIB$GET_SCREEN(NN)

C erase page
ISTAT=LIB$ERASE_PAGE(1,1)

C allocate choice for goats
IF(NN.EQ.'1')THEN

C set up menu for goats
ISTAT=LIB$PUT_SCREEN('Which goat aspect would you like to change? ',3,9)
ISTAT=LIB$PUT_SCREEN('1.- the stocking rate of goats (g/ha)',5,4)
ISTAT=LIB$PUT_SCREEN('2.- price of kids for meat',7,4)
ISTAT=LIB$PUT_SCREEN('3.- price of first cross doe kids',9,4)
ISTAT=LIB$PUT_SCREEN('4.- price of kids for scrub clearing',11,4)
ISTAT=LIB$PUT_SCREEN('5.- price of feral does & bucks',13,4)
ISTAT=LIB$PUT_SCREEN('6.- price of angora bucks',15,45)
ISTAT=LIB$PUT_SCREEN('7.- cashgora prices',17,45)
ISTAT=LIB$PUT_SCREEN('8.- cashmere prices',19,45)
ISTAT=LIB$PUT_SCREEN('9.- 1st & 2nd X wether prices',21,45)
ISTAT=LIB$PUT_SCREEN('10.- change the goat enterprise',23,45)
ISMAT=LIB$PUT_SCREEN('Your choice : ',16,5)

C allocate request for goats
ISTAT=LIB$PUT_CURSOR(16,19)
ISMAT=LIB$PUT_SCREEN(NN)

C allocate choice for goats
ISTAT=LIB$SET_CURSOR(1,1)
IF(NN.EQ.'1')THEN

C set up menu for goats
ISTAT=LIB$PUT_SCREEN('What is the new goat stocking rate (g/ha)?',10,5)
READ(5,149)GRATE
WRITE(UNIT=1,FMT=110,REC=1)COMMAND, DENSITY,*, COMMENT, GRATE
GOTO 200
ELSEIF(NN.EQ.'2')THEN

C set up menu for goats
ISTAT=LIB$PUT_SCREEN('What is the new price per meat kid? $/hd',10,5)
READ(5,151)KIDM
WRITE(UNIT=1,FMT=120,REC=2)KIDM, KIDX, KIDSC, FERAL, ANG, CASHG, CASHM, XANG
GOTO 200
ELSEIF(NN.EQ.'3')THEN

C set up menu for goats
ISTAT=LIB$PUT_SCREEN('What is the new first cross doe price? $/hd',10,5)
READ(5,152)KIDM
WRITE(UNIT=1,FMT=120,REC=2)KIDM, KIDX, KIDSC, FERAL, ANG, CASHG, CASHM, XANG
GOTO 200
ELSEIF(NN.EQ.'4')THEN

ISTAT=LIB$PUT_SCREEN('What is the price of
* progeny sold for scrub clearance ? $/hd',10,5)
  ISTAT=LIB$SET CURSOR(10,66)
  READ(5,153)KIDSC
  FORMAT(BN,F6.2)
  WRITE(UNIT=1,FMT=120,REC=2)KIDM,KIDX,KIDSC
  *,FERAL,ANGB,CASHG,CASHM,XANG
  GOTO 200
ELSEIF(NNN.EQ. '5')THEN
  ISTAT=LIB$PUT SCREEN('What is the price of
  * feral does & bucks ? $/hd',10,5)
  ISTAT=LIB$SET CURSOR(10,52)
  READ(5,154)FERAL
  FORMAT(BN,F6.2)
  WRITE(UNIT=1,FMT=120,REC=2)KIDM,KIDX,KIDSC
  *,FERAL,ANGB,CASHG,CASHM,XANG
  GOTO 200
ELSEIF(NNN.EQ. '6')THEN
  ISTAT=LIB$PUT SCREEN('What is the price for
  * angora bucks ? $/hd',10,5)
  ISTAT=LIB$SET CURSOR(10,47)
  READ(5,155)ANGB
  FORMAT(BN,F7.2)
  WRITE(UNIT=1,FMT=120,REC=2)KIDM,KIDX,KIDSC
  *,FERAL,ANGB,CASHG,CASHM,XANG
  GOTO 200
ELSEIF(NNN.EQ. '7')THEN
  ISTAT=LIB$PUT SCREEN('What is the new
  * cashgora price ($/kg) ?',10,5)
  ISTAT=LIB$SET CURSOR(10,46)
  READ(5,156)CASHG
  FORMAT(BN,F6.2)
  WRITE(UNIT=1,FMT=120,REC=2)KIDM,KIDX,KIDSC
  *,FERAL,ANGB,CASHG,CASHM,XANG
  GOTO 200
ELSEIF(NNN.EQ. '8')THEN
  ISTAT=LIB$PUT SCREEN('What is the new
  *cashmere price ($/kg) ?',10,5)
  ISTAT=LIB$SET CURSOR(10,46)
  READ(5,157)CASHM
  FORMAT(BN,F6.2)
  WRITE(UNIT=1,FMT=120,REC=2)KIDM,KIDX,KIDSC
  *,FERAL,ANGB,CASHG,CASHM,XANG
  GOTO 200
ELSEIF(NNN.EQ. '9')THEN
  ISTAT=LIB$PUT SCREEN('What is the new 1st
  * & 2nd X wether price ($/hd) ?',10,5)
  ISTAT=LIB$SET CURSOR(10,56)
  READ(5,158)XANG
  FORMAT(BN,F6.2)
  WRITE(UNIT=1,FMT=120,REC=2)KIDM,KIDX,KIDSC
  *,FERAL,ANGB,CASHG,CASHM,XANG
  GOTO 200
ELSEIF(NNN.EQ. '10')THEN
  ISTAT=LIB$PUT SCREEN('What goat enterprise
  * would you like ?',5,5)-
  ISTAT=LIB$PUT SCREEN('1.- dry feral does &
  * wethers (cashmere)',8,TO)
  ISTAT=LIB$PUT SCREEN('2.- 1st & 2nd cross
  * wethers (cashgora)',10,TO)
  ISTAT=LIB$PUT SCREEN('3.- feral does with
  * progeny sold for meat',12,10)
  ISTAT=LIB$PUT SCREEN('4.- feral does
  * crossed with angora buck, doe kids sold as first')
* START ISTAT=LIB$PUT SCREEN('cross breeders and wether kids for scrub clearance',15,15)
* ISTAT=LIB$PUT SCREEN('Your choice:',18,5)
ISTAT=LIB$SET_CURSOR(18,21)
READ(5,159)NCHOICE
FORMAT(EN,13)
WRITE(UNIT=1,FMT=150,REC=5)NCHOICE,MYEAR
GOTO 200
ELSE
GOTO 200
ENDIF
C **********************************************************
C adjust the command
ELSEIF(NN.EQ.'2')THEN
ISTAT=LIB$PUT SCREEN('Which command would you like - GOAT',10,5)
ISTAT=LIB$PUT SCREEN('CHEM',12,34)
ISTAT=LIB$SET_CURSOR(14,25)
ISTAT=LIB$SET_SCREEN('COMMAND')
WRITE(UNIT=1,FMT=110,REC=1)COMMAND,DENSITY
*,COMMENT,GRATE
GOTO 200
C **********************************************************
C allocate choice for sheep, set up menu for sheep
ELSEIF(NN.EQ.'3')THEN
ISTAT=LIB$PUT SCREEN('Which sheep aspect would you like to change?',3,9)
ISTAT=LIB$PUT SCREEN('1.- the price of wool',*,6,15)
ISTAT=LIB$PUT SCREEN('2.- the price of lambs,*,8,15)
ISTAT=LIB$PUT SCREEN('3.- the price of ewes',*,10,15)
ISTAT=LIB$PUT SCREEN('4.- the variable cost per ewe',12,15)
ISTAT=LIB$PUT SCREEN('Your choice:',15,5)
ISTAT=LIB$SET_CURSOR(15,19)
ISTAT=LIB$GET_SCREEN(NNN)
C allocate the request
IF(NNN.EQ.'1')THEN
ISTAT=LIB$PUT SCREEN('What is the new price of wool ($/kg) ?',10,5)
ISTAT=LIB$SET_CURSOR(10,44)
READ(5,160)WOOL
FORMAT(BN,F5.0)
WRITE(UNIT=1,FMT=130,REC=3)WOOL,LAMB,EWE,SVC
GOTO 200
ELSEIF(NNN.EQ.'2')THEN
ISTAT=LIB$PUT SCREEN('What is the new lamb price per head? ($/hd)',10,5)
ISTAT=LIB$SET_CURSOR(10,49)
READ(5,161)LAMB
FORMAT(BN,F6.2)
WRITE(UNIT=1,FMT=130,REC=3)WOOL,LAMB,EWE,SVC
GOTO 200
ELSEIF(NNN.EQ.'3')THEN
ISTAT=LIB$PUT SCREEN('What is the ewe price per head ($/hd)',10,5)
ISTAT=LIB$SET_CURSOR(10,49)
C allocate choice for chemicals, set chemical menu
ELSEIF (NNN .EQ. '4') THEN
C set the menu for chemicals
ISTAT = LIB$PUT SCREEN('Which chemical aspect
* would you like to change? ', 3, 9)
163 IS TAT = LIB$PUT SCREEN('1.- the price of 2,4,5-T
* (low volume)', 8, 15)
ISTAT = LIB$PUT SCREEN('2.- helicopter application
* (low volume)', 10, 15)
ISTAT = LIB$PUT SCREEN('3.- rate at which full
* potential is reached ', 12, 15)
ISTAT = LIB$PUT SCREEN('4.- which chemical aspect
* is the helicopter charge (low volume)? $/ha', 10, 5)
READ (5, 170) CHEM
170 FORMAT (BN, FN, 6.2)
WRITE (UNIT=1, FMT=140, REC=4) CHEM, RELIL, RELIR
GOTO 200
ELSEIF (NNN .EQ. '2') THEN
ISTR = LIB$PUT SCREEN('What is the new price
* for 2,4,5-T ($/l)?', 10, 5)
READ (5, 170) CHEM
170 FORMAT (BN, FN, 6.2)
WRITE (UNIT=1, FMT=140, REC=4) CHEM, HELIL, HELIH
GOTO 200
ELSEIF (NNN .EQ. '3') THEN
ISTR = LIB$PUT SCREEN('What is the helicopter
* charge (high volume)? $/ha', 10, 5)
READ (5, 171) HELIL
171 FORMAT (BN, FN, 6.2)
WRITE (UNIT=1, FMT=140, REC=4) CHEM, HELIL, HELIH
GOTO 200
ELSEIF (NNN .EQ. '4') THEN
ISTR = LIB$PUT SCREEN('Indicate proportions of
*...
* potential as decimals',5,5)
   DO I=1,10
      WRITE(PROMPT,173)I
      FORMAT('Year ',12,' =')
      ISTAT=LIB$PUT SCREEN(PROMPT,I+6,10)
      ISTAT=LIB$SET CURSOR(I+6,21)
      READ(5,174)CPROP(I)
      174  FORMAT(E4.3)
      IF(CPROP(I).EQ.1.0)THEN
         MYEAR=I
         GOTO 10
      ENDIF
   ENDDO
10  CONTINUE
C make chem example go six years so that annuity cashflow C can be calc. after the five year chemical application C redevelopment program stops
   IF(I.LT.6)THEN
      DO J=1+1,6
         CPROP(J)=CPROP(I)
         MYEAR=6
      ENDDO
   ENDIF
   WRITE(UNIT=1,FMT=180,REC=36)CPROP
   WRITE(UNIT=1,FMT=150,REC=5)NCHOICE,MYEAR
   GOTO 200
ELSE
   GOTO 200
ENDIF
C **************************************************
C allocate choice for gorse
ELSEIF(NN.EQ. '5')THEN
   ISTAT=LIB$PUT SCREEN('There are two choices * for gorse density',8,5)
   ISTAT=LIB$PUT SCREEN('Which would you prefer *- HIGH',10,5)
   ISTAT=LIB$PUT SCREEN('*- LOW',11,28)
   ISTAT=LIB$SET CURSOR(13,21)
   ISTAT=LIB$SET SCREEN(DENSITY)
   WRITE(UNIT=1,FMT=110,REC=1)COMMAND,DENSITY
   GOTO 200
ENDIF
C **************************************************
C set out data file data
ELSEIF(NN.EQ. '6')THEN
   ISTAT=LIB$SET CURSOR(1,1)
   WRITE(6,199)NXM
   199  FORMAT('Data file :',A10,16X,'CHEM pasture redev rep rate')
   C type out CPROP array
   M=80-(MYEAR*5)
   ISTAT=LIB$SET CURSOR(2,M)
   WRITE(6,214)CPROP(I),I,MYEAR
   214  FORMAT(E12.2,E5.2)
   ISTAT=LIB$SET CURSOR(3,10)
   WRITE(6,201)COMMENT
   201  FORMAT('Comment :',A60)
   ISTAT=LIB$SET CURSOR(4,10)
   WRITE(6,202)COMMAND
   202  FORMAT('Command :',A4)
   ISTAT=LIB$SET_CURSOR(5,10)
WRITE(6,203)DENSITY
FORMAT( DENSITY of gorse : ',A4)
ISTAT=LIBSSET CURSOR(7,10)
WRITE(6,204)GRATE,Wool

WRITE(6,205)KIDM,LAMB

WRITE(6,206)KIDX,EWE

WRITE(6,207)KIDX,EWE

WRITE(6,208)KIDX,SVC

WRITE(6,209)ANGB

WRITE(6,210)CASHG,CHEM

WRITE(6,211)CASHM,HELIL

WRITE(6,212)XANG,HELIL

WRITE(6,213)NCHOICE

WRITE(6,214)GOTO 200

C *********************************************************
C close the data file
C
ELSE
CLOSE(UNIT=1,DISPOSE=’SAVE’)
ENDIF
ISTAT=LIBSSET PAGE(1,1)
STOP
END
C this program sets up the initial data file for the goat/gorse simulation

PROGRAM INSET

DIMENSION A1(B), A2(B), A3(B), A4(B), A5(B), A6(B), A7(B), A8(B)

DIMENSION A10(B), A11(B), A12(B), A13(B), A9(B)

DIMENSION B1(B), B2(B), B3(B), B4(B), B5(B), B6(B), B7(B), B8(B)

DIMENSION B9(B), B10(B), B11(B), B12(B), B13(B), PAST(4)

DIMENSION C(4), D(4), PERC(4), CPROP(10)

CHARACTER *40 COMMENT
CHARACTER *60 WMLMEN
CHARACTER *4 COMMAND

REAL KIDM, KIDX, KIDSC, LAMB

FORMAT 2A4,A60,F5.0)

FORMAT 4F6.2

FORMAT 3F6.2

FORMAT 5F6.2

FORMAT 3F6.2

FORMAT 4F6.0

FORMAT 4F6.3

FORMAT 2F6.3

FORMAT 1OF6 .3)

OPEN (UNIT=1, NAME='DAT.DAT', STATUS='NEW',
*ORGANIZATION='RELATIVE', ACCESS='DIRECT',
*RECl=100, FORM='FORMATED' )

COMMAND='GOAT'

DENSITY='LOW'

COMMENT='This is the first data file'

GRATE=16.

KIDM=7.

KIDX=8.

KIDSC=13.

FERAL=13.

ANGB=250.

CASHG=14.25

WOOL=2.87

LAMB=14.77

CHEM=15.37

HELI=15.25

HELIH=45.79

CASHM=110.

XANG=40.

NCHOICE=1

MYEAR=10

EWE=26.

SVC=4.87

WRITE (UNIT=1, FMT=110, REC=1) COMMENT, DENSITY, GRATE

WRITE (UNIT=1, FMT=120, REC=2) FERAL, ANG, CASHG

WRITE (UNIT=1, FMT=130, REC=3) WOOL, LAMB, EWE, SVC

WRITE (UNIT=1, FMT=140, REC=4) CHEM, HELI, HELIH

WRITE (UNIT=1, FMT=150, REC=5) NCHOICE, MYEAR

C write in data for gorse % cover estimates

DATA A1/3.9, 2.9, 9.3, 14.0, 14.4, 13.3, 16.8, 21.1/

DATA A2/3.25, 2.75, 6.7, 9.8, 9.2, 8.8, 8.6, 14.8/

DATA A3/2.95, 2.57, 5.85, 7.8, 7.0, 6.6, 6.7, 9.7/

DATA A4/2.75, 2.34, 4.9, 6.4, 5.3, 5.0, 5.0, 7.5/

DATA A5/2.5, 2.17, 4.35, 5.6, 4.5, 4.1, 3.6, 4.8/

DATA A6/2.2, 2.01, 3.8, 5.1, 3.7, 3.5, 2.8, 3.3/

DATA A7/2.0, 1.9, 3.44, 4.5, 2.9, 2.8, 2.5, 1.9/

DATA A8/1.8, 1.85, 3.1, 4.1, 2.5, 2.4, 1.6, 0.9/

DATA A9/1.65, 1.8, 2.9, 3.7, 2.2, 1.8, 1.2, 0.5/

DATA A10/1.55, 1.2, 2.7, 3.4, 2.0, 1.4, 0.8, 0.5/

DATA A11/1.5, 0.25, 3.1, 1.8, 0.9, 0.65, 0.5/
DATA A12/1.44,0.,2.5,2.9,1.6,0.,0.4,0./
DATA A13/1.4,0.,2.4,0.,0.6,0.,0.,0./

C *******************************************************
DATA B1/0.,0.,0.,0.,0.,0.,0.,0.
DATA B3/6.,4.,6.,10.,10.,0.,4.,5.,
DATA B4/8.,10.,14.,14.,14.,8.,7.5./
DATA B5/12.,12.,18.,18.,18.,14.,12.5./
DATA B6/18.,18.,20.,22.,24.,22.,20.,17.5./
DATA B7/24.,24.,26.,28.,33.,28.,26.,25.5./
DATA B8/33.,28.,33.,40.,33.,33.,33.,0./
DATA 9/44.,40.,40.,48.,54.,44.,42.5./
DATA B10/54.,50.,50.,58.,60.,58.,66.0./
DATA B11/62.,0.,60.,70.,70.,100.,70.,0./
DATA B12/80.,0.,70.,100.,100.,0.,100.,0./
DATA B13/100.,0.,100.,0.,0.,0.,0.,0./

C write matrix onto the data file
WRITE(UNIT=1,FMT=150,REC=6)A1
WRITE(UNIT=1,FMT=150,REC=7)A2
WRITE(UNIT=1,FMT=150,REC=8)A3
WRITE(UNIT=1,FMT=150,REC=9)A4
WRITE(UNIT=1,FMT=150,REC=10)A5
WRITE(UNIT=1,FMT=150,REC=11)A6
WRITE(UNIT=1,FMT=150,REC=12)A7
WRITE(UNIT=1,FMT=150,REC=13)A8
WRITE(UNIT=1,FMT=150,REC=14)A9
WRITE(UNIT=1,FMT=150,REC=15)A10
WRITE(UNIT=1,FMT=150,REC=16)A11
WRITE(UNIT=1,FMT=150,REC=17)A12
WRITE(UNIT=1,FMT=150,REC=18)A13
WRITE(UNIT=1,FMT=150,REC=19)B1
WRITE(UNIT=1,FMT=150,REC=20)B2
WRITE(UNIT=1,FMT=150,REC=21)B3
WRITE(UNIT=1,FMT=150,REC=22)B4
WRITE(UNIT=1,FMT=150,REC=23)B5
WRITE(UNIT=1,FMT=150,REC=24)B6
WRITE(UNIT=1,FMT=150,REC=25)B7
WRITE(UNIT=1,FMT=150,REC=26)B8
WRITE(UNIT=1,FMT=150,REC=27)B9
WRITE(UNIT=1,FMT=150,REC=28)B10
WRITE(UNIT=1,FMT=150,REC=29)B11
WRITE(UNIT=1,FMT=150,REC=30)B12
WRITE(UNIT=1,FMT=150,REC=31)B13

C write the pasture prod'n records
DATA PAST/2322.,2016.,4185.,4455./
WRITE(UNIT=1,FMT=150,REC=32)PAST

C write C & D arrays concerning clover declines
DATA C/10.,6.,10.,12./
DATA D/35.,28.,35.,39./
WRITE(UNIT=1,FMT=160,REC=33)C
WRITE(UNIT=1,FMT=160,REC=34)D

C write PERC array for percent decrease in clover decline
DATA PERC/7.75,.50,.25,.0./
WRITE(UNIT=1,FMT=170,REC=35)PERC

C write CPROP array for increase sheep potential during chemical C application
DATA CPROP/0.33,0.40,0.45,0.50,0.55,0.60,0.70,0.80,0.90,1.0/
WRITE(UNIT=1,FMT=190,REC=36)CPROP

C close the file
CLOSE(UNIT=1,DISPOSE='SAVE')
STOP
END
APPENDIX 13

A DESCRIPTION OF SUBROUTINES THAT SIMULATE CLOVER, GORSE AND COMPLEMENTARY GRAZING

The GOATS subroutine keeps track of the time steps, grazing ratios and calls various subroutines when necessary. The GORSE subroutine in Appendix 11 determines the percentage of gorse cover depending on the time step and goat grazing proportions. Per cent clover on offer is simulated by subroutines CLOV1, CLOV2, CLOV3 and CLOV4 all listed in Appendix 10. CLOV1 subroutine simulates the per cent clover during the gorse decline phase given the time step and proportion of goats. The second phase of the clover simulation is handled by subroutines CLOV2 and CLOV3. CLOV2 sets up the arrays describing the amount of clover decline given prior goat proportions, while CLOV3 determines the actual clover per cent given the time step. Subroutine CLOV4 determines the clover percentage given the time step when clover production has returned to expected normal grazing levels. The final subroutine used is SHFD listed in Appendix 10. This subroutine uses the method of calculating feed availability to sheep outlined in section 4.5.2 (3).
# Appendix 14

**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></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>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>Capital Requirements</strong> (no land included)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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>: 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>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></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total Capital Requirements</strong></td>
<td>8164.</td>
<td>234.</td>
<td>234.</td>
<td>78.</td>
<td>78.</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>1980.</td>
<td>1980.</td>
<td>660.</td>
<td>660.</td>
</tr>
<tr>
<td>sheep: (wool $2.87/kg) (lambs $14.77/ha)</td>
<td>0.</td>
<td>3718.</td>
<td>3718.</td>
<td>4957.</td>
<td>4957.</td>
</tr>
<tr>
<td><strong>Total Return</strong></td>
<td>0.</td>
<td>5698.</td>
<td>5698.</td>
<td>5617.</td>
<td>5617.</td>
</tr>
<tr>
<td><strong>Variable Costs</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>burning</td>
<td>100.</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 ($3.69/hd)</td>
<td>0.</td>
<td>664.</td>
<td>664.</td>
<td>221.</td>
<td>221.</td>
</tr>
<tr>
<td>sheep ($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>4692.</td>
<td>1541.</td>
<td>1541.</td>
<td>1390.</td>
<td>1390.</td>
</tr>
<tr>
<td><strong>Cumulative Profit</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ANNUAL PROFIT</strong></td>
<td>-12856.</td>
<td>3923.</td>
<td>3923.</td>
<td>4149.</td>
<td>4149.</td>
</tr>
<tr>
<td><strong>IRR</strong></td>
<td>76.20%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>NPV at 5%</strong></td>
<td>$66288.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Benefit Cost Ratio at 5%</strong></td>
<td>1.08</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 14 (cont.)

GOAT OPTION: current prices, 18 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>540.</td>
<td>540.</td>
<td>540.</td>
<td>60.</td>
<td>60.</td>
</tr>
<tr>
<td>(initial goats = 18.00/ha)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></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>lambs %</td>
<td>0.0</td>
<td>90.0</td>
<td>95.6</td>
<td>92.6</td>
<td>90.0</td>
</tr>
</tbody>
</table>

CAPITAL REQUIREMENTS (no land included)

| goats: purchase - feral does & wths. (§ 13.00/hd) | 7020.| 702.| 702.| 78. | 78. |
| sales - feral (does & wths.) (§ 13.00/hd)       | 0.   | 0.  | 0.  | 6240.| 0.  |
| sheep: purchases (ewes) (§ 26.00/hd)            | 0.   | 0.  | 0.  | 6240.| 0.  |
| fencing: one hot wire                            | 1144.|     |     |     |     |

TOTAL CAPITAL REQUIREMENTS

| 8164.| 702.| 702.| 78. | 78. |

RETURNS

| goats: fibre - cashmere (§110.00/kg) | 0. | 5940.| 5940.| 660. | 660. |
| sheep: (wool § 2.87/kg) (lambs § 14.77/hd) | 0. | 0.  | 0.  | 5166.| 4957.|

TOTAL RETURN

| 0. | 5940.| 5940.| 5826.| 5617.|

VARIABLE COSTS

| burning                           | 100. |
| topdressing                      | 4592.|
| goats ($ 3.69/hd)                | 0.   | 1993.| 1993.| 221. | 221. |
| sheep ($ 4.87/hd)                | 0.   | 0.   | 0.   | 1169.| 1169.|

TOTAL COSTS


ANNUAL PROFIT

| -12856.| 3245.| 3245.| 4358.| 4149.|

CUMULATIVE PROFIT


IRR = 73.84%   NPV at 5% = $ 65209.   Benefit Cost Ratio at 5% = 1.02
## APPENDIX 15

### 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>YEARS</th>
<th>0.0</th>
<th>1.0</th>
<th>2.0</th>
<th>3.0</th>
<th>4.0</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 = 6.00/ha)</td>
<td>180.</td>
<td>180.</td>
<td>180.</td>
<td>60.</td>
<td>60.</td>
</tr>
<tr>
<td>changes in animal production:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>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>
</tbody>
</table>

| **CAPITAL REQUIREMENTS** (no land included) |     |     |     |     |     |
| goats: purchase - 1st & 2nd X wths. ($40.00/hd) | 7200. | 720. | 720. | 240. | 240. |
| sales - 1st & 2nd X wethers ($40.00/hd) | 0. | 0. | 0. | 4800. | 0. |
| sheep: purchases (ewes) ($26.00/hd) | 4680. | 0. | 0. | 1560. | 0. |
| fencing : one hot wire | 1144. |     |     |     |     |
| **TOTAL CAPITAL REQUIREMENTS** | 13024. | 720. | 720. | -3000. | 240. |

| **RETURNS** |     |     |     |     |     |
| goats: fibre - cashgora ($14.25/kg) | 0. | 2565. | 2565. | 855. | 855. |
| sheep: (wool $2.87/kg) (lambs $14.77/ha) | 0. | 3718. | 3718. | 4957. | 4957. |
| **TOTAL RETURN** | 0. | 6283. | 6283. | 5812. | 5812. |

| **VARIABLE COSTS** |     |     |     |     |     |
| burning | 100. |     |     |     |     |
| topdressing | 4592. |     |     |     |     |
| goats ($3.54/hd) | 0. | 637. | 637. | 212. | 212. |
| sheep ($4.87/hd) | 0. | 877. | 877. | 1169. | 1169. |
| **TOTAL COSTS** | 4692. | 1514. | 1514. | 1381. | 1381. |

| **ANNUAL PROFIT** |     |     |     |     |     |
| -17716. | 4049. | 4049. | 7431. | 4191. |

| **CUMULATIVE PROFIT** |     |     |     |     |     |

**IRR = 62.67%**  
**NPV at 5% = $65189.**  
**Benefit Cost Ratio at 5% = 0.99**
APPENDIX 15 (cont.)

GOAT OPTION: 2  current prices, 18 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>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>
</tbody>
</table>

<table>
<thead>
<tr>
<th>changes in animal production:</th>
<th>wool (kg/ewe)</th>
<th>lambing %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>90.0</td>
</tr>
<tr>
<td></td>
<td>4.84</td>
<td>95.6</td>
</tr>
<tr>
<td></td>
<td>4.67</td>
<td>92.6</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>90.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAPITAL REQUIREMENTS (no land included)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>goats: purchase - 1st &amp; 2nd X wths.</td>
<td>($ 40.00/hd) 21600. 2160. 2160. 240. 240.</td>
</tr>
<tr>
<td>sheep: purchases (ewes)</td>
<td>($ 26.00/hd) 0. 0. 0. 6240. 0.</td>
</tr>
<tr>
<td>fencing: one hot wire</td>
<td>1144.</td>
</tr>
<tr>
<td>TOTAL CAPITAL REQUIREMENTS</td>
<td>22744. 2160. 2160. -12720. 240.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RETURNS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>goats : fibre - cashgora</td>
<td>($ 14.25/kg) 0. 7695. 7695. 855. 855.</td>
</tr>
<tr>
<td>sheep : (wool $ 2.87/kg) (lambs $ 14.77/hd)</td>
<td>0. 0. 5166. 4957.</td>
</tr>
<tr>
<td>TOTAL RETURN</td>
<td>0. 7695. 7695. 6021. 5812.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VARIABLE COSTS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>burning</td>
<td>100.</td>
</tr>
<tr>
<td>topdressing</td>
<td>4592.</td>
</tr>
<tr>
<td>goats ($ 3.54/hd)</td>
<td>0. 1912. 1912. 212. 212.</td>
</tr>
<tr>
<td>sheep ($ 4.87/hd)</td>
<td>0. 0. 0. 1169. 1169.</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td>4692. 1912. 1912. 1381. 1381.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ANNUAL PROFIT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>-27436. 3623. 3623. 17360. 4191.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CUMULATIVE PROFIT</th>
<th></th>
</tr>
</thead>
</table>

IRR = 47.19%  NPV at 5% = $ 63255.  Benefit Cost Ratio at 5% = 0.92
### APPENDIX 16

**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>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>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>
</tbody>
</table>

| CAPITAL REQUIREMENTS (no land included) |
| goats: purchase - feral does ($13.00/hd) | 2399. |
| sales - feral does ($13.00/hd) | 0. |
| sheep: purchases (ewes) ($26.00/hd) | 4680. |
| fencing: one hot wire | 1144. |
| TOTAL CAPITAL REQUIREMENTS | 8223. |

| RETURNS | goats: progeny - meat ($7.00/hd) | 0. | 534. | 534. | 178. | 178. |
| sheep: (wool $2.87/kg) (lambs $14.77/hd) | 0. | 3718. | 3718. | 4957. | 4957. |
| TOTAL RETURN | 0. | 4252. | 4252. | 5135. | 5135. |

| VARIABLE COSTS |
| burning | 100. |
| topdressing | 4592. |
| goats: ($1.92/hd) | 0. | 345. | 345. | 115. | 115. |
| sheep: ($4.87/hd) | 0. | 877. | 877. | 1169. | 1169. |
| TOTAL COSTS | 4692. | 1221. | 1221. | 1284. | 1284. |

| ANNUAL PROFIT | -12915. | 3031. | 3031. | 3890. | 3851. |


**IRR = 69.73%**  
**NPV at 5% = $59452.**  
**Benefit Cost Ratio at 5% = 0.96**
APPENDIX 16 (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>
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<th>4.</th>
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<tr>
<td>PHYSICAL DATA</td>
<td></td>
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<td></td>
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</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>
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<tr>
<td>no. of sheep</td>
<td></td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>240.</td>
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<tr>
<td>changes in animal production: wool (kg/ewe)</td>
<td></td>
<td>0.0</td>
<td>4.50</td>
<td>4.84</td>
<td>4.67</td>
</tr>
<tr>
<td>lambing %</td>
<td></td>
<td>0.0</td>
<td>90.0</td>
<td>95.6</td>
<td>92.6</td>
</tr>
<tr>
<td>CAPITAL REQUIREMENTS (no land included)</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>goats: purchase - feral does (§ 13.00/hd)</td>
<td>7196.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
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<tr>
<td>sheep: sales - feral does (§ 13.00/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>6396.</td>
<td>0.</td>
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<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>6240.</td>
<td>0.</td>
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<tr>
<td>fencing: one hot wire</td>
<td>1144.</td>
<td></td>
<td></td>
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<td></td>
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<td>TOTAL CAPITAL REQUIREMENTS</td>
<td></td>
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<tr>
<td></td>
<td>8340.</td>
<td>0.</td>
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<td>-156.</td>
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<td>RETURNS</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>goats: progeny - meat (§ 7.00/hd)</td>
<td>0.</td>
<td>1603.</td>
<td>1603.</td>
<td>178.</td>
<td>178.</td>
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<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>
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<tr>
<td>TOTAL RETURN</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.</td>
<td>1603.</td>
<td>1603.</td>
<td>5344.</td>
<td>5135.</td>
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<td>VARIABLE COSTS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>burning</td>
<td>100.</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: purchase - feral does (§ 1.82/hd)</td>
<td>0.</td>
<td>1035.</td>
<td>1035.</td>
<td>115.</td>
<td>115.</td>
</tr>
<tr>
<td>sheep: sales - feral does (§ 4.87/hd)</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>1169.</td>
<td>1169.</td>
</tr>
<tr>
<td>TOTAL COSTS</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>4692.</td>
<td>1035.</td>
<td>1035.</td>
<td>1284.</td>
<td>1284.</td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>-13032.</td>
<td>568.</td>
<td>568.</td>
<td>4217.</td>
<td>3851.</td>
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<td>CUMULATIVE PROFIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</table>

IRR = 61.05%  NPV at 5% = $55038.  Benefit Cost Ratio at 5% = 0.70
**APPENDIX 17**

**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>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>no. of sheep</td>
<td>180</td>
<td>180</td>
<td>180</td>
<td>240</td>
<td>240</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>changes in animal production</th>
<th>wool (kg/ewe)</th>
<th>lambing %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>90.0</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>90.0</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>90.0</td>
</tr>
<tr>
<td></td>
<td>4.50</td>
<td>90.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CAPITAL REQUIREMENTS (no land included)</th>
</tr>
</thead>
<tbody>
<tr>
<td>goats: purchase - feral does ($13.00/hd)</td>
</tr>
<tr>
<td>- angora bucks</td>
</tr>
<tr>
<td>sales - feral does ($13.00/hd)</td>
</tr>
<tr>
<td>- angora bucks</td>
</tr>
<tr>
<td>sheep: purchases (ewes) ($26.00/hd)</td>
</tr>
<tr>
<td>fencing: one hot wire</td>
</tr>
</tbody>
</table>

**TOTAL CAPITAL REQUIREMENTS**

9414. 1105. 1105. -382. 368.

<table>
<thead>
<tr>
<th>RETURNS</th>
</tr>
</thead>
<tbody>
<tr>
<td>goats: progeny - 1st. cross does ($80.00/hd)</td>
</tr>
<tr>
<td>sheep: (wool $2.87/kg) (lambs $14.77/hd)</td>
</tr>
</tbody>
</table>

**TOTAL RETURN**

0. 10414. 10414. 7189. 7189.

<table>
<thead>
<tr>
<th>VARIABLE COSTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>burning topdressing goats ($1.89/hd)</td>
</tr>
<tr>
<td>sheep ($4.87/hd)</td>
</tr>
</tbody>
</table>

**TOTAL COSTS**

4692. 1217. 1217. 1282. 1282.

<table>
<thead>
<tr>
<th>ANNUAL PROFIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-14106.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>CUMULATIVE PROFIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-14106.</td>
</tr>
</tbody>
</table>

**IRR = 98.31%**

**NPV at 5% = $ 97503.**

**Benefit Cost Ratio at 5% = 1.53**
APPENDIX 17 (cont.)

GOAT OPTION: 4  current prices, 18 goats per hectare

(Land area = 30 ha)

<table>
<thead>
<tr>
<th>YEARS</th>
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<th>1.</th>
<th>2.</th>
<th>3.</th>
<th>4.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PHYSICAL DATA</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 goats</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>240.</td>
<td>240.</td>
</tr>
<tr>
<td>no. of sheep</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
<td>0.</td>
</tr>
</tbody>
</table>

| changes in animal production: wool (kg/ewe) | 4.50 | 4.84 | 4.67 | 4.50 |
| laming % | 90.0 | 95.6 | 92.6 | 90.0 |

| CAPITAL REQUIREMENTS (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. |
| : sales - feral does ($13.00/hd) | 0.  | 0.  | 0.  | 0.  | 0.  |
| - angora bucks ($250.00/hd) | 0.  | 0.  | 0.  | 0.  | 0.  |
| sheep: purchases (ewes) ($26.00/hd) | 0.  | 0.  | 0.  | 0.  | 0.  |
| fencing: one hot wire | 1144. |

| TOTAL CAPITAL REQUIREMENTS | 11664. | 3315. | 3315. | -2632. | 368. |

| RETURNS |
| goats: progeny - 1st. cross does ($80.00/hd) | 0.  | 17280. | 17280. | 1920. | 1920. |
| - scrub wths. ($13.00/hd) | 0.  | 2808. | 2808. | 312. | 312. |
| sheep: (wool $2.87/kg) (lambs $14.77/hd) | 0.  | 0.  | 0.  | 5166. | 4957. |

| TOTAL RETURN | 0.  | 20088. | 20088. | 7398. | 7189. |

| VARIABLE COSTS |
| burning | 100.  | 4592. |
| topdressing goats ($1.89/hd) | 0.  | 1022. | 1022. | 114. | 114. |
| sheep ($2.87/hd) | 0.  | 0.  | 0.  | 1169. | 1169. |

| TOTAL COSTS | 4692. | 1022. | 1022. | 1282. | 1282. |

| ANNUAL PROFIT | -16356. | 15752. | 15752. | 8748. | 5538. |

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

IRR = 117.60%  NPV at 5% = $11620.  Benefit Cost Ratio at 5% = 2.02
## Appendix 18

**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>
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<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>85.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
<td>100.0</td>
</tr>
<tr>
<td>No. of sheep</td>
<td>162.0</td>
<td>230.0</td>
<td>270.0</td>
<td>270.0</td>
<td>270.0</td>
<td>270.0</td>
<td>270.0</td>
</tr>
</tbody>
</table>

| **Capital Requirements** |   |   |   |   |   |   |   |
| (no land included) |   |   |   |   |   |   |   |
| Sheep: purchase (ewes) | ($ 26.00/hd) | 4212.0 | 1755.0 | 1053.0 | 0.0 | 0.0 | 0.0 |

| **Returns** |   |   |   |   |   |   |   |
| (wool $ 2.87/kg) (lambs $ 14.77/hd) | 0.0 | 3346.0 | 4751.0 | 5577.0 | 5577.0 | 5577.0 | 5577.0 |

| **Variable Costs** |   |   |   |   |   |   |   |
| Burning | 100.0 | 4592.0 | 5492.0 | 5492.0 | 5492.0 | 5492.0 | 5492.0 |
| Topdressing | 0.0 | 692.0 | 692.0 | 692.0 | 692.0 | 692.0 | 692.0 |
| Chemical 2,4,5-T |   | 2306.0 | 692.0 | 692.0 | 692.0 | 692.0 | 692.0 |
| Helicopter application - high vol. | ($ 45.79/ha) | 1374.0 | 0.0 | 458.0 | 458.0 | 458.0 | 458.0 |
| Helicopter application - low vol. | ($ 15.25/ha) | 0.0 | 789.0 | 1120.0 | 1315.0 | 1315.0 | 1315.0 |
| Sheep: variable costs | ($ 4.87/hd) | 0.0 | 8371.0 | 1938.0 | 2269.0 | 2464.0 | 2464.0 |

| **Total Costs** | 8371.0 | 1938.0 | 2269.0 | 2464.0 | 2464.0 | 2464.0 | 1855.0 |

| **Annual Profits** | -12583.0 | -347.0 | 1428.0 | 3113.0 | 3113.0 | 3113.0 | 3722.0 |

| **Cumulative Profit** | -12583.0 | -12930.0 | -11502.0 | -8389.0 | -5277.0 | -2164.0 | 1558.0 |

| IRR | 40.62% | NPV at 5% = $ 51616.0 | Benefit Cost Ratio at 5% = 0.96 |
## APPENDIX 19

**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>
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<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>
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<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>
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<td>CAPITAL REQUIREMENTS (no land included)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep : purchase (ewes)</td>
<td>($) 26.00/hd</td>
<td>2314.</td>
<td>2319.</td>
<td>772.</td>
<td>842.</td>
<td>772.</td>
<td>0. 0.</td>
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<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>
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<td>4957.</td>
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<td>5577.</td>
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<tr>
<td>topdressing</td>
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<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>0.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
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<tr>
<td>- low vol.</td>
<td>($) 15.25/ha</td>
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<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
<td>458.</td>
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<tr>
<td>sheep : variable costs</td>
<td>($) 4.87/hd</td>
<td>0.</td>
<td>433.</td>
<td>867.</td>
<td>1013.</td>
<td>1169.</td>
<td>1315.</td>
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<td>1867.</td>
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</tr>
</tbody>
</table>

IRR = 39.39%     NPV at 5% = $ 48791.     Benefit Cost Ratio at 5% = 0.84
APPENDIX 20

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>
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<th>3.</th>
<th>4.</th>
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<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>
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<tr>
<td>no. of sheep</td>
<td>162</td>
<td>189</td>
<td>216</td>
<td>243</td>
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<td>270</td>
<td>270</td>
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<tr>
<td>(no land included)</td>
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<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>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sheep :</td>
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<td>3346</td>
<td>3904</td>
<td>4461</td>
<td>5019</td>
<td>5577</td>
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<td></td>
<td></td>
</tr>
<tr>
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<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</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>high vol.</td>
<td>($ 45.79/ha)</td>
<td>1374</td>
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</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>TOTAL COSTS</td>
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<tr>
<td></td>
<td>8371</td>
<td>1938</td>
<td>2070</td>
<td>2201</td>
<td>2333</td>
<td>2464</td>
<td>1855</td>
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<td></td>
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<td>1984</td>
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<td>-12583</td>
<td>-11877</td>
<td>-10745</td>
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IRR = 40.10%  NPV at 5% = $ 50079.  Benefit Cost Ratio at 5% = 0.90
APPENDIX 21
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>
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<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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</thead>
<tbody>
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<td></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>
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</table>

PHYSICAL DATA

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<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>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>
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</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>
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</table>

CAPITAL REQUIREMENTS (no land included)

<table>
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<th>sheep : purchase (ewes)</th>
<th>($26.00/hd)</th>
<th>2106.</th>
<th>702.</th>
<th>702.</th>
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RETURNS

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<tr>
<th>sheep : (wool $2.87/kg) (lambs $14.77/hd)</th>
<th>0.</th>
<th>1673.</th>
<th>2231.</th>
<th>2788.</th>
<th>3346.</th>
<th>3904.</th>
<th>4461.</th>
<th>5019.</th>
<th>5577.</th>
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VARIABLE COSTS

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<th>procedure</th>
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<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>burning</td>
<td>100.</td>
<td>4592.</td>
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</tr>
<tr>
<td>helicopter application - high vol.</td>
<td>($45.79/ha)</td>
<td>0.</td>
<td>394.</td>
<td>526.</td>
<td>657.</td>
<td>789.</td>
<td>920.</td>
<td>1052.</td>
<td>1183.</td>
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TOTAL COSTS

<table>
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<th>0.0</th>
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<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>-10477.</td>
<td>-573.</td>
<td>-146.</td>
<td>280.</td>
<td>706.</td>
<td>1132.</td>
<td>2167.</td>
<td>2594.</td>
<td>3722.</td>
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ANNUAL PROFITS

<table>
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<th>2.0</th>
<th>3.0</th>
<th>4.0</th>
<th>5.0</th>
<th>6.0</th>
<th>7.0</th>
<th>8.0</th>
</tr>
</thead>
</table>

IRR = 29.47%  NPV at 5% = $44396.  Benefit Cost Ratio at 5% = 0.87