A FARM-LEVEL MODEL TO EVALUATE THE IMPACTS OF CURRENT ENERGY POLICY OPTIONS

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THE AGRICULTURAL ECONOMICS RESEARCH UNIT
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PREFACE

The study on which this report is based forms part of a research programme at Lincoln College aimed at understanding the likely effects of energy shortages and energy price rises on the New Zealand economy and on the farm sector in particular. The present study was completed by Mr A. Thompson whilst working in the Unit as a postgraduate fellow and as an assistant research economist.

Other reports emanating from this programme include AERU Research Report No. 80, "The Energy Requirement of Farming in New Zealand", and AERU Discussion Paper No. 40, "New Zealand Agriculture and Oil Price Increases".

The present report details a linear programming approach to understanding the likely reaction of a mixed cropping farm in Canterbury to a reduction in fuel availability or an increase in fuel price. The reaction is measured through changes in enterprise mix under a profit maximising assumption.

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P.D. Chudleigh

Director.

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CHAPTER 1

INTRODUCTION

1.1 Background

In October 1973, the Organisation of Petroleum Exporting Countries (OPEC) placed an embargo on the production of crude oil for export which resulted in major disruptions in the economies dependent on world markets for petroleum and petroleum products. The legacies of that policy have been apparent in the subsequent and continuing increases in the price of petroleum brought about by a restatement of market power towards the producers of a resource from which a large proportion of the world energy supply is derived. The repercussions of dependence on petroleum were demonstrated in many economies and the embargo underscored the likely economic impacts on these countries of oil supply shortfalls. It was the realisation of the world's reliance on oil supplies, and the vision of a future without oil which has made governments focus attention upon what is often called "the Energy Crisis" to stimulate research and development into ways of reducing dependence on imported petroleum.

1.2 Terminology Throughout the study, distinction is made between the terms energy (the aggregate of scarce power resources such as the fossil fuels and electricity), petroleum (crude oil and its part-refined derivatives) and petroleum fuels (specific to the crude oil-based fuels which are largely used in transport). These are the direct inputs of energy. Indirect energy is a measure of the amount of direct energy sequestered in the production and distribution of any product. Both indirect and direct energy are expressed in terms of a common unit, the joule. The rate of energy flow of one joule per second is equivalent to one watt.

1.3 The Energy Problem

Much of the concern over future energy supplies stems from the importance of petroleum in world transport energy supplies and the predictions of escalating petroleum prices in the near future. Looking into the longer term, the prospect of a future without oil is especially concerning because of the current high dependence of many economies on oil. As an example of oil dependence, in the year ended June 30th 1978, of New Zealand's total direct energy consumption (in fuels, gas, coal and electricity) of 330PJ,[1] 166PJ was from imported petroleum and refined petroleum fuels. Adjustment from this level of dependence on oil-based energy

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1 Based on the energy unit of the joule, one peta joule (PJ) is 10^{15} joules. Elsewhere reference is made to mega joules (10^6 joules) and gigajoules (10^9 joules). Energy consumption data calculated from New Zealand Department of Statistics (1978a : 41-42) using energy conversion factors from Dawson (1978: 71).

poses significant long term problems which can only be overcome by successful technology research to locate and develop suitable energy types to replace fossil fuels[2]. Technology development is traditionally a slow moving process: van Arsdall (1977: 1071) and Doering (1977: 1066) argue that significant alternatives will not become available for quite some time and certainly not until after the escalation of world petroleum prices.

Technology therefore is not progressing fast enough to alleviate or avoid the consequences of the energy problem that will occur in the shorter run. Oil prices would escalate if oil demand outstrips oil production and many believe this point will be reached before the year 2000. Attempting to be more specific on the likely date, in 1978 British Petroleum Limited and M.King Hubbert (DSIR 1978: 23,24) projected current world oil production peaking in the 1990's and a continuation of present oil demand growth trends. This analysis indicated the date of escalation would fall between 1985 and 1995[3]. The effect of policies by the oil exporters to resist growth in world oil production could well be to advance this date. With technology unlikely to provide significant alternatives until after world oil prices have escalated

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2 The need for energy technology research as a priority has been recognised in New Zealand for some time. Since 1972, government involvement in this area has been directed through the Ministry of Energy Resources and substantial funding of specifically energy related research has been channelled through the New Zealand Energy Research and Development Committee (NZERDC).

3 A view shared by others, including Doering (op. cit.).

the burden of high imported petroleum prices occurring over the next 10-20 years will fall on final consumers through higher prices (if the free markets are allowed to work) and on economies through trade imbalances. Furthermore, oil prices increasing in real terms imply greater internal pressures within economies for increased inflation. Table 1.1 shows that the symptom of a rising real price of imported petroleum fuels has been apparent in New Zealand since about 1973.

TABLE 1.1

Price Indices, 1971-77

Year	Crude Petroleum	Imported fuels	All Imports	Consumer Prices
1971	1000	1000	1000	1000
1973	1052	1053	1095	1158
1975	3239	3248	1627	1475
1977	5282	5301	2445	1972
1978	5340	5359	2589	2207[a]

[a] The base for this figure is changed from December 1977 to 1971. Source: New Zealand Department of Statistics (1979: 72-78).

The detrimental effects on the economy would be lessened if consumers reduced their consumption of oil imports in response to the increased real price of oil. Over this period (1971 to 1978) the volume of imports has not fallen significantly, reinforcing the case that the demand for petroleum products is typically price inelastic (Dvoskin and Heady, 1976(a):5). If this inelasticity is maintained in the situation of rapidly rising oil prices, increased inflationary pressures and oil import costs are inescapable.

In New Zealand's case, any decline in the balance of payments caused by rising oil import costs could be worsened substantially by reduced export performance in the agricultural sector, almost the entirety of the country's exports being of primary agricultural products. If the agricultural sector as a whole cuts production in response to increased costs of energy inputs then export revenues would tend to decline further.

The level of export revenues also depends on the export prices received; upward changes in commodity prices may enhance export revenues, but given the highly variable nature of prices in world markets, consistent increases in real commodity prices are unlikely (and thus cannot be relied on) to alleviate the effects of high energy prices.[4]

Export performance is also influenced by the competitive cost advantage which New Zealand agriculture has in the past maintained over foreign producers. Costs of production have been so low that export produce could be transported to markets far overseas and be

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[4] Commodity prices have not increased significantly in response to increased fuel prices experienced after the oil embargo. Since 1973 the prices received by farmers have actually fallen significantly relative to the prices paid for inputs. This measurement is the agricultural terms of trade index which fell between 1973 and 1978 from 1358 to 876 (New Zealand Meat and Wool Board's Economic Service 1978 : 7).

sold at prices competitive with foreign producers in their own domestic markets whilst remaining profitable to the New Zealand farmer. The high transport energy cost incurred in shipping exports to traditional markets in Europe is sensitive to rising world petroleum prices and transport costs are likely to rise. Farmers may feel the consequences through dampened or reduced export prices, causing a decrease in the margin of profit for New Zealand agriculture. Such a loss of competitive cost advantage over producers in other countries would weaken agriculture's incentive to produce for export.

1.4 The Need for Energy Studies

The Government's role in management of the economy necessitates a commitment to resolving the long-term energy problem through encouragement of technology research and development. This commitment is already recognised through the Ministry of Energy and the New Zealand Energy Research and Development Committee (N.Z.E.R.D.C).

There is additionally a need to meet the problems of high oil prices in the shorter run with a consistent government policy on energy. Weakened export performance of the agricultural sector must be avoided, especially at a time of rapidly rising oil import costs, because of the severely detrimental impacts likely on the balance of payments. These effects could last into the longer-term future if weakened performance leads to falling rural incomes, rural employment and farm investment. Only when the internal consequences (change in production, incomes etc.) have been understood and quantified can the true cost to the country of high oil prices be calculated. Once this has been done, the costs of alternative policies can be assessed and compared to determine whether or not adoption of any other policy would be to the benefit of the country.

Within this need for economy-wide studies there can be identified areas which, because of their key importance to the overall economy, require more detailed study. Often the level of detail attainable in a national model will be so general as to omit major changes that can occur within sectors and where such a sector is of great importance to the economy, internal impacts would be wrongly estimated. In New Zealand, the agricultural sector plays such a vital part in the economy (being the largest exporting sector by far) that a more detailed study of the sector is required than can be provided by a national level model.

Critical factors in the selection of an energy policy are the effects that high energy prices would have on agricultural output, incomes and export performance. An industry or sub-sectoral level study can more accurately assess such changes than a national level approach. Study at the micro-economic level has the advantage that the producer's reaction of changing the allocation of resources (and thus the efficiency with which they are employed) on the farm can be taken into account, whereas the aggregated models often have to assume that the technical efficiency of agriculture is fixed in the short run. The latter analyses thus ignore the real response of input and product substitution that can occur as relative prices change. Allowing for such changes, producer level studies can better assess the true internal effects on output, incomes and resource use on subsections of the agricultural sector.

1.5 Study Objectives

The objectives of this study are threefold. They are to:

(i) examine previously published energy studies which may provide guidance on a suitable methodology and an insight into the relationships that exist between energy and economic performance parameters;

(ii) construct a valid model of some area typical of agricultural activity in New Zealand at the level of an individual producer to demonstrate the links between energy, input prices and farm output so that changes in the levels of farm performance parameters in response to various energy scenarios can be estimated, and

(iii) use this model experimentally to investigate the impacts likely to occur on agricultural activity (including farm incomes, systems, output, resource use of both direct and indirect energy inputs) and thus quantify the internal costs incurred and benefits gained as a consequence of current energy policy options.

Specifically the policies considered are those which lead to:

(i) increased fuel prices[5], or

(ii) reduced fuel availability (at constant prices).

<u>1.6 Subject of the Study</u> The particular farm studied is the mixed cropping farm at Lincoln College. The farm operates to return high net revenues from the production of small seeds (for pasture grasses and clover), cereals, pulse and processing vegetables in conjunction with sheep enterprises. The advantages of choosing this type of farm for an energy model are:

(i) The choice of alternative enterprises is not as confined by soil type or climate as on many farms in other parts of New Zealand (on which it may only be technically feasible to graze sheep)[6].

(ii) The use of direct and indirect energy inputs is more intensive than on non-cropping farms. The wide variety of inputs and methods used in mixed cropping allows more scope for substitution to occur.

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5 A policy to tax petroleum use would have the same on-farm effect as a market-induced price increase, and thus consequences of both can be shown through analysis of price increases alone.

6 The diversity in climate and soils is very wide in New Zealand and no tests have been attempted to illustrate whether the farm operates in truly average conditions. Furthermore, farm policy objectives and husbandry practices may similarly not be representative of mixed cropping farms in New Zealand. It would be incorrect to assert that it is a truly representative farm without testing these points.

In the event of a petroleum fuel shortage this farm type would seem to have the greatest ability, opportunity and need to alter its pattern of production. The particular farm has maintained in recent years detailed monthly operational records so input and output data are readily available[7].

1.7 Methodological Approach

A modelling technique is required which will duplicate the behaviour of the farm production system as the economic environment changes. If it is to be successful the model must be consistent not only with the physical view of the farm (that would be gained by examining it at a point in time) but also the way it behaves, or reacts to stimuli and changes over time. To gain the physical view the model must account for the many enterprises existing (and alternatives to them) and the way that these compete for the use of resources on the farm. It must take into account important differences between the various types of resources such as land, labour and capital, some of which are fixed in short run supply, and some of which are variable.

To gain a view of the behaviour of the farm over time, the model must be consistent with the objectives of the farm and must mimic the way in which these objectives are attained, and measured. The stated objective of the study farm is to

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[7] Published in Farm Bulletins.

return high net revenues. However, there are additional elements in the farm's objective function which are not explicitly stated, the most obvious and important being the management's attitude towards risk. Because this attitude is not stated, and decisions are often based on a subjective 'feeling', modification of the stated objective to account quantitatively for risk characteristics is not an easy task. Clearly there are clues which may point towards illuminating the attitudes to risk : the observation that net revenue maximisation was not in the stated objective of farm policy may itself indicate an aversion to riskiness, since under unconstrained profit maximisation, the level of risk is unimportant to the manager. However difficult it is to assess and quantify such characteristics of farm system behaviour, the methodology must have as its aim emulation of all the relevant features applying in the case of the study farm.

An additional criterion for selection of a methodology is that the data requirements of any model must not be greater than the data that can be assembled with the resources available. Generating data is a time-consuming process. Developing an over-detailed data set for use in a simple model is wastefulof resources, as is selecting a model which requires more data than can be generated. The model must be compatible with the constrained availability of data.

Indications of the successful uses and strong points of available methods can be gleaned from published studies and some of these are reviewed in the following chapter to give an idea of the models, the relationships between energy and agricultural performance parameters and to guide the choice of methodology.

Data available and an assessment of the problem characteristics that influence the choice of approach are described prior to selection of a modelling methodology in Chapter 3. Specification of the model is laid out in the same chapter. The ability of the mixed-cropping farm model to resemble the important physical characteristics and to mimic the behaviour of the farm is tested in Chapter 4. Results are shown and conclusions drawn in Chapters 5 and 6. A bibliography and appendices to the text appear at the end of the Report.

CHAPTER 2

REVIEW OF PREVIOUS ENERGY STUDIES

Prior to the actions of OPEC in 1973, petroleum prices had been declining in real terms throughout much of the 1950's and 1960's (Carter and Youde, 1975). It was not until after 1973 and the advent of rising real oil prices that the need for research into the energy future was widely accepted. Published energy studies examining the policy implications of energy shortages and high prices did not appear until some time later because these required an adequate base of energy data to be developed[8]. Many of the economic models first to appear were macro-level studies aimed at economic policy and planning aspects of the problem[9]. Relatively few concentrated specifically on agriculture and the likely impacts of the energy problem on food production and prices. This chapter reviews some of the latter studies.

Studies of the energy situation and its likely impacts on the agricultural economy have approached the problem using several methods and have generally been applied at either of three levels within the economy. The format of the following section is stratified according to whether the analyses described have been made at the national, regional or farm levels of agricultural activity.

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8 This period of data development occurred from 1973 onwards. Early studies generating energy coefficients for products include Leach and Slesser (1973), Wright (1974), Herendeen and Bullard (1974).

9 Such studies include Nicolau (1977), Nordhaus (1974), Yokell (1978), Mead (1978), Hudson and Jorgenson (1978), Hillman and Bullard (1978) and Manne (1976).

2.1 Energy Studies at the National Level

Comparing two scenarios of high energy prices and reduced energy supplies, Dvoskin and Heady (1978) found that uses of fuel which are only marginally profitable are cut under both scenarios. Production shifts to the more extensive farming systems where the marginal product of fuel is high, using more land to meet national food production targets (because of lower associated yields than under intensive systems). The difficulties in bringing more land into agricultural production are likely to result in shortfalls of national food production and food prices may rise in consequence (although the extent of food price rises likely and the modifying effects such price rises will have on production systems are not investigated).

The total effect at the farm level is difficult to infer from this model. The initial move to introduce extensive methods of production will result in falling output per hectare, and falling farm revenues. High energy prices and reduced energy supplies will both act to increase the unit cost of production.

At the onset of reduced agricultural output reaching the U.S. markets, food prices may increase. This would increase the unit return to farmers, but whether this provides sufficient a rise to offset higher farm costs will depend both on the price elasticity of demand for the particular crop and the suitability of the crop to low intensity production methods. The model does not investigate these net farm income effects.

A most interesting result that stems from a policy of expanded agricultural export production is that the increased value of exports (assuming world market prices are not adversely affected) is more than sufficient to offset the increased cost of importing greater quantities of oil.

Dvoskin and Heady's linear programming model does not take into account the effect that increased farm product prices may have since output prices are held constant throughout. Useful additional information comes from input-output studies which have the capability of determining the magnitude of product price changes for given input price changes (assuming there is no change in physical flows of inputs and products). The same modelling method can be altered by assuming constant prices to examine the effect that reduced energy supplies may have on the physical flows of outputs. An example of the pricing input-output model (termed the dual version) is given by Polenske (1978), showing that in response to a 20 per cent increase in coal prices in the U.S. economy, price increases occur in the products of many other sectors, including a 0.2 per cent rise in farm machinery prices. For the model of physical flows (termed the primal version), Penn et.al. (1976) show that an oil import supply cut of one million barrel-days (below 1972 imports to the U.S.A.) leads to a three per cent drop in U.S. agricultural output.

The effects of high energy prices and supply restrictions are rather more detrimental to agriculture than to other sectors. Parsons et.al. (1978) show that increases in the prices of U.K. agricultural sector products are greater than the average for all sectors (i.e. assuming sector cost increases are handed on in higher prices, the greater product price increases in agriculture reflect a greater impact of energy prices on costs). Hoffman and Jorgensen (1977) show a decline in U.S. agricultural output relative to the output of other sectors. Thus, agriculture is shown to be more vulnerable to energy supply changes than other sectors.

There are likely to be relative shifts in profitability between enterprises within agriculture. In response to doubled oil prices, glasshouse products and cereals grown in the U.K. will increase in price by 40 and 37 per cent respectively, whereas the average price increase over the agricultural sector is 35½ percent (Parsons et.al,(1978). It may seem, therefore, that such products would tend to be disadvantaged relative to other productive enterprises. However, this result does assume, as mentioned above, that increased costs can be handed on to the consumer. This is only true in the extreme case of complete price inelasticity of demand; to determine the net effect on profitability it is important to account for the full market reactions that determine new product price levels. Additionally, input-output models treat as constant the technical efficiency of sectors: it may be that agriculture is more or less able to adjust resource use than other sectors, and this effect should also be considered.

Increases in grain market prices are confirmed by Watt et.al.(1975) who show that U.S. production of grain also increases. This is not necessarily inconsistent with decreased <u>agricultural</u> output since output of non-cereals may decline rapidly. Increased demand for land exists and land prices become increased, slowing the transfer of rural land to urban uses. Results also confirm discussion earlier on export expansion policies; increased oil import costs are more than offset by increased export revenues.

Final changes likely in incomes to any sector cannot be assessed until the effect of market forces has been superimposed on production cost changes. In general food prices will rise as energy becomes more scarce and it is likely that those elements of the world's population whose money incomes do not depend directly on the level of farm revenues will suffer a decrease of income in real terms. This observation has serious implications for developing countries where large parts of the domestic population are urban poor and self-sufficient rural peasants (Timmer, 1975). For the peasant, the few inputs purchased that are necessary to maintain subsistence food output become more expensive whilst there is little or no surplus production sold to gain the advantage of increased food prices. To alleviate the increasing pressures towards starvation, governments must develop policies that recognise the interdependence of national economic, energy and social objectives.

2.2 Energy Studies at the Regional Level

Examining Californian agriculture, Adams et.al.(1977) use a quadratic programming model to estimate changes in regional agriculture in response to high energy prices and reduced energy supplies. When nitrogen fertiliser alone, and nitrogen with fuel together is reduced in availability or increased in price, production shifts to less intensive field crops, reducing the area under vegetables. Use of extensive methods reduces yield and total output: to compensate there is expansion of land in agriculture, a result similar to that shown by the national level models.

The net effects on the level of farm incomes are detrimental even taking into account the increases likely in crop product prices. Despite vegetable production declining more markedly than field cropping the value of vegetable output holds better than the value of field crops because of the greater price elasticity of demand for vegetables in California. However, in absolute terms all crop production decreases in value, because lost revenue from falling output is not made up for by increased product prices. Thus, the movement towards a more extensive agricultural base using less energy in total and more land tends to reduce farm incomes.

Flood et.al.(1975) use an input-output model to estimate the effects of energy supply restrictions on regional employment in Oklahoma. Comparison with other sectors shows that agriculture uses less energy input per worker than in most other sectors. The implication is that employment in the Oklahoma agricultural sector is less prone to reduced energy supplies than other sectors.

This study shows input-output ratios for agriculture as similar to those occurring in many other sectors; agricultural output would be affected only as badly as output from other sectors by reduced energy supplies.

2.3 Energy Studies at Farm Level

Examination of various effects of energy scenarios on agriculture at farm level enables more detail to be gained on exactly how the results of larger scale models (e.g. movement to extensive production, reduction of farm incomes, reduction of employment and substitution of inputs) will actually be implemented on farms. Results of large-scale models must be modified if detailed study at the farm level exposes some assumptions made in the large scale models as being unreasonable.

Hughes et.al.(1974) model intensive beef units on the basis of feeding, housing and stocking technologies used and the economic and energy costs associated with each. Measured in these terms the most efficient beef feedlots in the future will have covered cattle housing, bunker silo silage storage and will use low priced heifer calves. The systems simulation model shows that, at least for the short-run future, the least cost unit size for intensive feedlots is around 300. Producers with such a system will be less affected by increased energy costs and reduced supplies than producers with different systems.

The move to extensive production is in some cases only marginally feasible. Mapp and Dobbins (1977) examine one such area, in northwest Oklahoma, where existing cropping systems rely heavily on energy to provide irrigation water. A programming model of a farm typical of the region is used to determine how the existing systems can change under the two main energy scenarios to remain economically viable.

Pumping costs in the area tend to increase over time as artesian water levels drop, and the faster the rate of water extraction the more rapidly well levels decline. Whilst reduced tillage does save energy in cultivation, there is an associated greater demand for irrigation water. Under high energy prices pumping costs increase at a rapid rate (caused by greater extraction (well-level decline occurring at a greater rate) and by high pumping-energy prices). Even under relatively small energy price increases, farm incomes decrease substantially because productive resources are forced into dryland production.

Analysis of farm costs and incomes on three diverse Nicaraguan farms shows the effect that rising energy costs have on relative farm incomes (Warnken, 1976). A traditional farm using little imported energy and achieving moderate yields is contrasted with a developed farm using more intensive methods to achieve higher yields and a greater absolute farm income. The third is an intermediate farm some way between the two. Under conditions of stable energy costs relative to commodity prices there is an incentive to traditional farmers to intensify production and gain greater absolute income. However, rising relative energy costs cause this income incentive to become eroded and may thus dampen growth of national output and income, creating a stagnating effect on the process of agricultural development.

A similar analysis is carried out by Partridge (1977) on three farms typifying those predominating in three distinct climatic zones of Australia. A fifteen per cent increase in petroleum price raises farm costs and reduces farm incomes by 3.5 per cent on average. The zones where fuel expenditure is a high proportion of total costs are affected worst: they are the pastoral and the wheat-sheep zones.

2.4 Summary

Comparison of high energy prices and energy rationing shows the effects of the two to be very similar. Production methods tend to become more extensive; despite expansion of cropped land area, total output is likely to fall, especially so in the case of products of intensive farming systems. Declining food output will tend to increase food prices, although at differential rates, depending on the price elasticity of a particular commodity. Where food prices are not allowed to increase (as in the farm level models) farm output value, agricultural exports and farm sector incomes become diminished under both high energy prices and energy rationing. These effects are rapidly reduced and may even be reversed as commodity prices are allowed to rise.

Although farm production systems, costs and incomes are quite sensitive to reduced fuel use and increased prices for energy, the likely eventual reaction depends on relative changes in the prices received for various farm commodities, for models show that farm parameters are very sensitive to output price changes. Clearly, output price assumptions have a critical influence on the outcome of energy price changes at the farm level.

Where examined, the policy to expand agricultural output for exporting countries is feasible. Increased imports of energy at higher prices would be offset by increased volume exports from the U.S. agricultural sector (assuming commodity prices do not fall in response) and farm incomes could be maintained.

Generally, these studies show that the high energy prices imminent in the near future are likely to lead to a contraction of agricultural output. Small savings in imported fuel are greatly offset by declining export volume from agricultural sectors. Inelasticity of food demand is expected to raise food prices, but not by sufficient a margin to offset completely the decreases in producers' incomes or export revenues.

CHAPTER 3

DATA AND MODEL SPECIFICATION

The choice of a methodology and the development of a working model is influenced to some degree by the type and quality of data that are already available. Such data are described and discussed in the preliminary sections of this chapter. Later sections lay out the specification of the model of Lincoln College's mixed cropping farm.

3.1 Existing Data Base

Four sources of information form the foundations on which the model is constructed. These are

1. published Lincoln College farm's records and budgeting manuals
2. published agronomic research results and communications with agronomists
3. an unpublished report on fuel use on the College's mixed cropping farm [Clark (1978)]
4. a published thesis cataloguing the indirect energy requirements of farm inputs [Dawson (1978)]

<u>3.1.1 Farm Records and Budgeting Manuals</u>. Lincoln College Farm Bulletins are records of operations carried out by month on the College farms. Such operations reported are for each individual paddock and include cultivations used and the

application of sprays, fertilizer, seed and irrigation water. Resultant yields of cash crops on the mixed cropping farm are also recorded, again by paddock. Each paddock can therefore be used as one observation of the physical relationship that exists between the levels of inputs and the level of output of each crop system. Combining observations of the same crops grown in various dispersed paddocks in one season, the individual observations of each relationship are averaged to partially account for the effect on yield of the varied soil types existing on the farm. Each crop relationship treated in this way is generalised for all soil types thus encountered; differences in yields between the 15 soil types occurring in regular patches over the farm are not known and soils variation on crop yield cannot be explicitly modelled from these data.

Bulletins are also available for some previous years, providing observations from various seasons accounting for different patterns of weather (and pest incidence). With additional input and output information from past seasons, the relationships can be further modified to account for changes over time. In this way the relationships for some of the crops[10] can be established (where recorded) which are representative of varied climatic conditions and soil types.

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[10] Unfortunately this detail of information is not available for inputs (grazing intakes, chemicals) to sheep enterprises from farm records.

Lincoln College's Department of Farm Management and Rural Valuation update annually a Farm Budget Manual, the financial section of which provides a comprehensive listing of prices for farm inputs and products sold.

These financial data enable the physical flows of inputs and outputs already established to be converted into flows of costs and revenues. This gives the dimension of profitability to the model, bringing in the concept of relative prices, the stimulus which triggers product and input mix substitutions to enhance farm incomes.

The financial section of the Farm Budget Manual also contains examples of gross margins for selected crop and stock activities. These proved most useful in specifying inputs to and outputs from a sheep breeding flock, which is included in the model. The technical section provides metabolisable energy coefficients (used as feed values in the model) for the various forages and conserved feeds which can be utilised by stock.

<u>3.1.2 Agronomic Research Reports</u>. Where data are required to specify crop production methods which have not been used on the mixed cropping farm in recent years (or which have not been recorded, for example forage crop yields and rates of liveweight gains in fattening hoggets) other sources of information must be sought. The farm's supervisor and the manager combined judgements to provide subjectively average

estimates of yield levels in cereal crops grown under varying programs of cultivations (reduced and conventional methods), sowing dates (winter and spring drilling) and water application (irrigation and non-irrigation) for given inputs of fertiliser, sprays and seeding rates and taking into account local climate and soils. Data on the yield response of other crops to varying input mixes and treatments are often available only from published agronomic work or from personal communication with researchers. Whilst these data derived from external sources are not specifically representative of the study farm, research results from Canterbury are preferred as a 'next best' source of data because of their consistency with the Canterbury environment.

3.1.3 Direct Energy Use Data. Clark (1978) examined the total use of diesel fuel on the mixed cropping farm at Lincoln in 1977, to determine for each paddock (and thus each productive use) the amounts of fuel used. Whilst no records of fuel use by paddock are kept the object is to apportion the known total use of diesel amongst crops using M.A.F. data for each of the machinery operations recorded for each paddock. For the purposes of the model, one general purpose tractor owned by the farm (a Massey Ferguson 165) is used as the basis for all calculations of fuel and tractor hours demand by crops. Cultivation operations are split into heavy, medium and light work rates for this tractor, and fuel consumption and work rates (hectares per hour) are selected according to these categories.

In addition, Clark presents the estimated fuel consumption and work rates for a Claas combine harvester (as used on the study farm), and these rates too are incorporated in model calculations of direct energy usage.

From available records the total use of petrol fuels could not be so easily apportioned because the large number of petrol driven vehicles on the farm are used for a diversity of purposes and usage, often not directly attributable to any particular paddock, crop or enterprise. The exception is petrol used in off-farm cartage of inputs (seed, fertilizer and lime) and outputs (grain, fat lambs, peas and wool) which the model incorporates utilising rough estimates of the rates of work and fuel consumption for the farm's seven ton truck (see Appendix 1).

3.1.4 Indirect Energy Use Data. Dawson (1977) lists for most farm inputs estimates of the requirement for direct energy in the production and distribution of farm inputs to the New Zealand farm gate. Recognising that the farm sector has an additional reliance on energy over and above direct energy in the form of fuel is important: on the mixed cropping farm indirect energy accounts for 60 percent of total farm energy use. The links existing between direct and indirect energy inputs will ensure that as high direct energy prices and shortages occur, prices and availabilities of other inputs will also change, an impact which would be ignored if direct energy use only were modelled.

Inclusion of both direct and indirect energy coefficients adds a further dimension to the model. Physical flows on inputs and outputs can additionally be measured in terms of energy flows, and changes within the farm system can be assessed in terms of energy substitutions of inputs, energetic efficiency of production and total energy requirements as well as in terms of economic and physical parameters.

3.2 The Mixed Cropping Farm : Modelling Methodology

Having reviewed data available, a methodology needs to be selected which takes into account not only the data, but also behavioural characteristics of the study farm.

3.2.1 Suitability of Data to Modelling Methods.

Observations of outputs of each crop are in practice only available for a limited number of alternative input mixes since the methods of husbandry used on the farm seldom change from year to year. For example, seed rates, fertilizer applications and herbicide sprays used on one crop within and between years tend to be similar, determined by past experience. Each input level, if changed in isolation, would have an unknown effect on the crop output (that is the marginal products of each input are indeterminate) and production functions cannot be modelled exactly. For some crops there is only one observation of the production mix available during the past years if the crop has only been grown once and to estimate the true production surface from such little data would involve a very high degree of complexity and risk of error: the data do not bear extrapolating to obtain a high degree of model detail. For this reason, a system simulation model is not the most appropriate for this study.

What is known is that in past years from a repeated (and unchanging) pattern of inputs per hectare of x_1 units of machinery, x_2 kilograms of fertilizer, x_3 kilograms of seed, and x_4 dollars worth of sprays there is an average response of y tonnes of wheat yield. A programming type of model can readily incorporate data of this type and would seem a more appropriate method to use if a model of farm system behaviour consistent with established farm practices is required.

3.2.2 Problem Characteristics and Selection of a Modelling Methodology. In order to derive compatibility of behaviour between model and the farm, there must be compatibility of the model with essential characteristics of the study farm. On the basis of data available, choice of a methodology seems to favour a programming model. Not only are these models consistent with the data available, but they are also consistent with certain imperfections, for example the continuation of established patterns of husbandries (implying there is a resistance to marginal changes in input mixes, even if they would increase net revenue). Only certain well-tried combinations of inputs are generally observed in use on the farm, and this feature is adequately suited to a programming treatment.

Another characteristic of the farm, central to its behaviour is accommodated by programming models which can provide for optimisation (maximisation or minimisation) of an objective function. It has been assumed that the farm manager acts in such a way that optimises some objective function (which may comprise elements of profit, with or without risk, and non-monetary costs and benefits) because this ensures that resources are used in a way that is 'best'. Optimisation, therefore, may be very useful to indicate the most rational (i.e. the 'best' and thus the most likely) changes to be made in the farm system in response to changed energy availabilities and prices. Optimisation can represent the characteristic rationale behind the farm manager's desision, and therefore provides the mechanism to show the behaviour of the system. Monte Carlo programming which provides near optimal solutions randomly, would not be as useful since it is the direction of rational change likely, and not the range of change that will indicate trends in input use, energy use, production and net revenues on the farm.

No explicit treatment of risk is incorporated in this model. Use of data that are average for farm budgeting and planning decisions tacitly assumes a neutral attitude to risk. However, in practice, farm managers are likely to modify decisions based on such data in the light of their subjective perception of, and attitude towards risk. This implies that risk is important in the true objective functions of mixed cropping farmers and helps explain the behaviour of the farm system under conditions of change[11]. It would aid the realism if such characteristics could be introduced successfully into the model.

Linear programming models have been found to be of limited use in representing systems under complex stochastic and risk environments. Theoretically, the riskiness associated with a course of action could be catered for by attaching quantifiable coefficients (reflecting the probability and degrees of success or failure) to the particular elements of the objective function prone to risk. The risk environment would then act to vary the level of profitability of each enterprise. Such a simplistic approach belies the complexities of risk, which can originate from many sources, mostly exogenous to the farm. In order to model risk itself

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[11]Study of any one farm in isolation (especially a College farm) may not reflect attitudes typical of all mixed cropping farmers, but risk is still likely to be important to the farm manager (although perhaps less so to the College farm management than to other mixed cropping managers) and will positively influence his decision-making.

comprehensively as it affects agriculture, it is therefore necessary to look outside the farm system. In practice, a complete treatment of risk is a demanding task and often the alternative is to introduce a simplified version. Previous studies have shown that risk incorporation, where used in linear programming, has tended towards oversimplification, and has been cumbersome to operate. Adams et al (1977) conclude that unless risk treatment is comprehensive, it is likely to be unhelpful.

It has already been hinted that some account of risk can be made implicitly, if not explicitly, in the formulation stage of a linear programme model (p 31). If true average data are used there is an implication of risk neutrality, a lack of concern for the variation that does naturally occur. Selecting only those crops proven on the Canterbury plains for inclusion in the model effectively presents the model farm manager the choice only of known risks. Modelling only those systems and husbandries that are widely in practice has the same effect in that it is held that the risks involved in these practices are at an acceptable level. Thus, whilst maximising profit for the farm, the alternative systems modelled can be selected so that they are consistent with a level of risk that is acceptable to the farm manager. Even if explicit treatment is impractical, risk is not altogether left out of this model.

Within this L.P. model an essential characteristic to incorporate is the 'bulkiness' of certain capital items, including buildings, plant and machinery. The mere fact that the farm already owns two combine harvesters may lead to an exaggeration of the area under cereals, above the optimal area if these machines could be purchased in fractions. In the programming models integer activities (only being able to adopt whole number values) can be specified, and these are used in the farm cropping model to represent the ownership and fixed costs of tractors, implements, combine harvesters and irrigation equipment. The actual machine use per annum is variable but is restricted to being below a certain maximum (capacity) level and the variable costs associated with use of the machine are determined in real activities, separated from the fixed costs. The incorporation of real and integer activities is referred to as mixed-integer programming.

3.2.3 Model Design : Representation of Real Farm Characteristics. The model of the mixed cropping farm at Lincoln College represents the alternative productive activities in which the farm could be engaged. It mimics the rational behaviour of the farm manager by assuming that his motivation is to maximise the level of farm profits attained through careful selection of a feasible combination of productive activities. The formal objective of the model is to locate the organisation of production which maximises profit, defined here as total revenue less variable and semi-fixed costs. To enable this, for each feasible productive activity, the associated revenues and input requirements expressed per unit of activity operation (for example per hectare, or stock unit) are specified.

The farm manager can exercise control over the farm system by selecting different crops, by allocating inputs to the same crops in different ways or by changing the proportions of land under each crop. He will use these controls to change the system when farm profits can be increased by so doing. However, there are constraints within which he must exercise this control. For example, the size of the farm imposes a land constraint and the climate restricts the number of different crops which it is feasible to grow. Thus environmental factors and resource availability act to restrict the changes which the farm manager can make to maximise the level of farm income generated. The model incorporates these and other constraints on the system identifying them as the "real" constraints.

Under experimentation with the model into scenarios of high energy prices and restricted direct energy supplies, the rational behaviour to maintain the highest level of profit possible will involve changes in resource allocation and in patterns and methods of production as relative input prices and availabilities change. Enterprise selection is likely to alter. In order to simulate the interactions between energy price and other input prices to define the likely relative changes in the price of each input (the stimulus for resource re-allocation) it is necessary to treat each input separately within the model to assign to each coefficients reflecting their price and energy requirement. The extended treatment of inputs involves an expanded linear programming matrix, with the addition of the necessary accounting constraints and input supply activities. Separation of individual inputs by type through the accounting constraints allows energy price and supply parameters to be reflected in input levels and enterprise selection.

3.3 Model Specification

The particular aspects of the farm's operation that are modelled are described below divided into sub-sections on productive activities, real, artificial, and accounting constraints on input use, and the net revenue objective function. The problem data are fed into the computer in the form of a matrix of 67 rows (constraints) and 99 columns (activities). Groupings by sub-matrices are shown in Table 3.1 and are referred to later in the text by the relevant particular letter (from a. to r.).

Table 3.1 The Linear Programming Problem Matrix

CONSTRAINT TYPE	INPUT	PRODUCTIVE ACTIVITIES: CROPS (CEREALS, CASHBREAK, STOCKFEED)	PRODUCTIVE ACTIVITIES: SHEEP	NON-PRODUCTIVE ACTIVITIES: INPUT SUPPLY	NON-PRODUCTIVE ACTIVITIES: FEED SUPPLY	INEQUALITY SIGN	RIGHT HAND SIDE
Real	Land	a. Periodic land demand				≤	Total arable area (T.A.A)
	Land	b. Rotation of crops				≤	1st cereals 2nd cereals 1st cereals Break crops
	Land	c. Irrigated land demand				≤	Total irrigable area
	Land	d. Fertility				≥	0
Artificial	Land	e. Farm policy on land area under cereals and pasture seeds				≥	$\frac{1}{3}$ T.A.A.
	Feed transferred		i. Periodic feed demand		n. Quality 1 feed transferred to quality 2 pool	≥	0
Accounting	Variable Inputs	f. Variable input requirements		k. Purchase variable inputs		≤	0
	Semi-fixed inputs	g. Semi-fixed input requirements		l. Purchase semi-fixed inputs		≤	0
	Live-stock feed	h. Periodic supply of feed by crops	j. Periodic feed demand	m. Purchase or sell stock-feed	o. Feed supply by transfer over time	≤	0
	Total energy			p. Energy requirement		>	0
Objective Function		q. Unit revenues		r. Unit costs			

3.3.1 Productive Activity Specification. Two sheep flock systems and 32 crop activities represent the productive alternatives appropriate to the farm. This is by no means a comprehensive coverage of all the possible combinations of crop types, yields and input mixes but this selection provides a wide base of alternatives to the current system. The number of different crops considered are:[13] wheat, barley, oats (for green feed), tick beans, peas, kale, fodder beet, rape, ryegrass, white clover, lucerne and pasture. These are crops commonly grown in Canterbury and are therefore proven feasible for the Canterbury soils and climate. No exotic crops are included because, in general, high yield variability is a feature of such crops when grown in marginal climatic conditions.

Productive activities are described under five sub-sections on livestock, cereals, pasture seeds, peas/ beans and fodder/forage crops.

1. Livestock.

Two sheep enterprises are modelled as farm-owned stock activities capable of utilizing crop residues and plant wastes. These include a permanent breed-

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13 Since the alternative methods of producing these outputs are treated as separate activities, the true production function for wheat is represented by 12 different combinations of input mixes and output. This duplication of activities for single crop types is used for most crops and the 12 different crops considered are entered in a total of 32 activities.

ing flock for fat lamb production and a hogget fattening activity operating from February to October only(Table 3.2). A third stock activity is included implicitly in the model, and this involves contract grazing, a means of selling surplus feed on the farm which is grazed *in situ* by other farm's flocks. In recent years, the farm has adopted the latter policy of contract grazing to utilise feed, rather than running a farm-owned sheep enterprise. Because the sheep grazed have not been owned by the farm, actual input and output data have not been entered in the farm's records.

Feed requirements (sub matrix j) are estimated from M.A.F. feed budgeting data and are apportioned over each time period depending upon age of fattening animals and on the phase of the ewe's breeding cycle. Requirements are calculated on the basis of metabolisable energy, feed quality being split into two broad categories of high (greater than nine megajoules of metabolisable energy per kilogram of dry matter) and low quality. All inputs to the sheep enterprises are shown in Appendix VII. Set stocking rates are not used to allocate feed: the number and type of animals supportable is balanced with feed supply in each model period.

TABLE 3.2

Livestock Activities

	Description
SHEEP 1 (Corriedales)	Permanent breeding flock with one ram per 50 ewes. Breeds own replacements, culls all five year olds. Capital cost of the initial flock is taken as an annual charge equivalent to the interest payable.
SHEEP 2	Hogget fattening enterprise, buying 15 kg hoggets in February and selling them fat in October at between 40 and 45 kilograms. Capital cost is included. Target live-weight gain is 100 grams per day.

2. Cereals.

For the Canterbury mixed cropping farmer, cereals crops are of great importance as a stable, low risk income source. Other cash crops are prone to widely fluctuating prices and variable yields (e.g. clover and ryegrass) so cereals are often regarded as a principal part of the farmer's rotations. Guaranteed wheat prices are fixed before the season and generally yields are not susceptible to the fine changes in weather which influence small seeds crops. Given the importance of the cereals crop both to farmer's incomes and to consumer's food demand patterns, it may be essential to maintain cereals cropping as much as is possible in a difficult energy situation, perhaps by applying energy- conserving methods of production. In view of this, the model has 14 cereals activities which are variations on the current conventionally cultivated spring sown or autumn sown wheat and spring sown barley. These activities are shown below in Table 3.3. (also see Appendix VIII for inputs, yields and revenues (sub matrices f, g and q.)).

TABLE 3.3

Cereals Activities Showing Alternative Production Systems

Crop Activity	Sowing	Non-Irrigated	1st/2nd year	Tillage Practiced
AWHEAT 1A	Autumn	Non-irrigated	1st year	Conventional
AWHEAT 1B	"	"	2nd year	"
AWHEAT 2A	"	"	1st year	Reduced
AWHEAT 2B	"	"	2nd year	"
SWHEAT 1A	Spring	"	1st year	Conventional
SWHEAT 1B	"	"	2nd year	"
SWHEAT 2A	"	"	1st year	Reduced
SWHEAT 2B	"	"	2nd year	"
SWHEAT 3A	"	Irrigated	1st year	Conventional
SWHEAT 3B	"	"	2nd year	"
SWHEAT 4A	"	"	1st year	Reduced
SWHEAT 4B	"	"	2nd year	"
BARLEY 1A	Spring	Non-irrigated	1st year	Conventional
BARLEY 1B	"	"	2nd year	"

TABLE 3.4

Pasture Seed Activities

Crop	Description
Tama Ryegrass (intensive)	High input, high output. Provides ryegrass straw and grazing early in the season in addition to seed crop. Irrigated
Manawa Ryegrass (non-irrigated)	Similar high cost crop to Tama with lower cultivations resulting in low yields of seed and hay.
Tama Ryegrass	A lower cost alternative with less fertilizer and spray, medium cultivations and low seeding rate. Seed yield is between those of Intensive Tama and Manawa; not grazed but baled for hay.(Based only on data of one year's crop from one paddock.)
White Clover (irrigated)	Huia white clover, undersown with spring wheat and all ryegrasses. Irrigated, grazed in early season, no hay is baled. Low fertilizer costs.
White Clover	As white clover (irrigated) but non-irrigated, lower yielding.

3. Pasture Seeds

The production of pasture seeds (Table 3.4) is a general description of activities included in the model and is also a feature of Canterbury mixed cropping farm systems. A good seed crop is lucrative and the following crop of grass either for hay or grazing meets the need for a cereals break crop. The effect on soil structure is beneficial and nitrogen fixed in root nodes of clovers can reduce greatly the need for artificial, high energy intensity nitrogen fertilizers. The small seed crops currently grown are the cultivars Tama and Manawa Ryegrass and Huia white clover; the latter is the most important (in terms of area) of the seed crops on the study farm.

TABLE 3.5

Pea and Bean Cash Crop Activities

Crop	Description
Contract peas for freezing (var. Greenfeast)	Irrigated, low sprays and high cultivations. Harvested by works machinery gangs costed at equivalent farm rates. High net revenues. Area grown and revenue resulting depend on contract.
Seed peas. (var. Maples)	Non-irrigated, peastraw yield is higher. Very low fertilizer costs, low cultivations and net revenues.
Tick beans	Autumn sown, non-irrigated, low cultivations, high harvesting costs. Area grown subject to contract quota.
Tick beans	Spring grown, irrigated, low sprays, higher yield.

4. Peas / Beans

The four remaining cash crop activities are the pulses, peas and beans (see Table 3.5). For the season 1977-78 the contract for freezing peas was of 17 hectares and for tick beans was of 10 hectares. These quotas are liable to marked inter-seasonal variation and for the short-run future it is assumed that the contracts will remain close to the 1978-79 season levels.

5. Fodder / forage crops

TABLE 3.6

Fodder and Forage Activities

Forage Crop		Description
Fodder Beet		High fertilizer and cultivations, low spray. Long growing season for April-June grazing.
Kale		High sprays and cultivations, low yield due to short season. February grazing. Early sown Choumoellier.
Kale 2		High sprays and cultivations, higher yields due to longer seasons growth. May-June grazing, later sown Choumoellier.
Giant Rape		Medium sprays, high cultivation. A short season providing grazing in February.
Amuri Oats - as a winter greenfeed		Minimum cultivations, no sprays. Alternative to winter fallow. May-June grazing.
Lucerne	seven-year stand, both crops irrigated	No hay made. High fertilizer. Establishment costs spread over the seven years
Lucerne 2	five-year stand	High establishment costs. Higher machinery and fuel costs from haymaking.
Pasture	Both follow clover	Year round grazing. No hay made.
Pasture 2	No establishment costs (bar seed). Irrigated.	Year round grazing. Higher machinery and fuel costs from haymaking.

Fodder crops and forage activities to produce grazing and conserved feeds are described above in Table 3.6. All crops are strip-grazed <u>in situ</u> using electric fences and all except for greenfeed oats, are irrigated. Time of grazing and feed yields of fodder/forage activities are shown in Appendix III. Sheep are grazed to requirements only and no concentrates are given.

3.3.2 Non-Productive Activities. The activities in this category represent resource flows and allow inputs to productive activities to be monitored. Three sub-groups involved are input supply, feed supply and contracting activities.

1. Input Supply

Input supply activities monitor the total demand for each individual input and calculate the costs and energy requirements involved in supplying sufficient inputs to meet demand. Twenty-one input activities are included in the model monitoring and costing the separate inputs of:

fertilizers - ammonium sulphate
- nitrogen supersphosphate
- turnip and rape superphosphate
- superphosphate
- 30 percent potash superphosphate

lime

pesticide sprays

fuel - diesel
- petrol (used in off-farm cartage)

sheep chemicals and treatments (two separate groups)

sheep cartage

materials cartage

variable inputs of machinery - tractors
- implements
- combine harvesters
- irrigation

fixed inputs of machinery - tractors
(integer value only) - implements
- combine harvesters
- irrigation

general, non energy inputs - services

Cost and energy requirements coefficients (sub-matrices r and p) for fertilizers, lime, chemicals and direct energy inputs are straightforward to determine from farm records whereas for cartage and machinery, the calculation of these coefficients is more involved. The variable costs of different machines per hour's use and the fixed costs per annum are calculated as shown in Appendix I. These calculations depend heavily on the assumptions regarding the allocation of depreciation and repairs to either fixed or variable elements. In order that only whole machines can be owned by the farm, the fixed cost elements for tractors, combine harvesters and implements are specified as integer activities.

Cartage costs are derived from the total annual costs of owning the farm's seven tonne Bedford truck expressed per kilometre use in an average year of 5000 kilometres of cartage. These average fixed costs per kilometre are added to estimated running costs incurred on an average round trip to Christchurch, fully laden for one part of the journey. In this way an average total cost per seven tonne load to Christchurch is calculated. Coefficients representing inputs to the cartage activity are expressed per seven tonnes so that the truck only journeys with the equivalent of a full load in one direction and in an average round trip carries no less than seven tonnes of materials in total.

For all machinery, the variable running costs do not include fuel; this is extracted from variable costs, being entered as a flat rate cost per machinery hour. Fuel use is incorporated into the demand constraints for diesel or petrol so that variations, caused by differing cultivation requirements are accounted for.

2. <u>Feed Supply</u>

Feed supply activities are more numerous, numbering 41. Of these, 28 represent purchasing and selling of stock feeds of the two different qualities in each of seven model time periods. Prices for purchase and sale of conserved feeds (i.e. second quality) are assumed constant over all periods through the year. The assumed prices at which sales can be made by the farm is lower than the effective price at which the farm can purchase feed. Storage and bale carting costs are not included in these prices. The effective cost to the farmer buying bales of feed will often be higher than the price alone (received by the vendor) since when sold on an "in the field" basis, the purchaser incurs the additional cost of collection and transport of the bales. This is allowed for by imputing price differentials between purchased and sold feed[14].

First quality feed prices are assumed as standard whether for purchase or sale but both vary according to the time of year (that is, depending on seasonal feed supply). Feed prices per megajoule are calculated from estimates of per head per week agistment(contract grazing) fees prevailing in the Lincoln area during winter and summer.

Of the remaining 13 feed supply activities six allow that second quality feed can be stored and transferred between periods through the year to sale during the most profitable period. This option has been assumed costless (because of lack of data) whereas storage is not actually so. The last seven are activities representing the emergency use of high quality feeds

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14 No data are available on collection costs so price differences used are set arbitrarily.

on the farm where low quality feeds are in short supply. High quality feed is assumed to be grazed in the paddock, and in order that cropping sequences and land requirements are not disrupted (by forage in the ground being carried over to periods beyond their cropping cycle) the model assumes that these feeds can not be transferred through time (stored).

3. Contracting

In a situation where a farm has idle machinery (e.g. tractors, implements, harvesters) and labour, and also where there is local demand for such resources contracting is often used to meet these needs. Knowing that professional and local contracting services are available the farmer can reduce the equipment he would necessarily need to own, and can decrease inefficient under-employment of marginal labour. To the farmer with surplus resources, contracting-out may earn a revenue that will cover variable costs and contribute to the annual fixed costs associated with machinery and labour. The model accommodates the possibilities of contracting-in and contracting-out activities by incorporating them in machinery supply/demand constraints.

Whilst there are no limits to the contribution contracting-in (from neighbours and contractors) can make to meeting the farm's machinery requirements there are likely to be limitations on the extent that a farm can contract-out: the farmer is subject to local demand conditions and his only purpose in seeking to contract-out is to use his idle resources (not, it is assumed, to enter the contracting business). Timeliness and the need for specialist machinery may produce serious limitation to local demand. For these reasons, the possible scale of contracting-out activities has been artifically restricted in the model to an arbitrary annual ceiling equal to the annual capacity of each machine. In this way, the farm cannot be deliberately over-stocked by one or more machines (either tractors or combine harvesters): there will not be any machine owned by the farm which can be used entirely for contracting-out.

Professional contractors' charges are used to cost contracting-in, and contracting-out is arbitrarily set at a slightly lower level between professional rates and average total costs of operating the machinery.

3.4 The Constraints on Activity Selection

The problem solution is restricted by several groups of constraints. Within the bounds of these constraints is located an area of feasible solutions. Three types of constraints act to define the feasible area of solutions for the mixed cropping farm. These are each broken down within the three subgroups into the component parts of the whole problem tableau, shown as sub-matrices or row vectors.

<u>3.4.1 The Real Constraints</u>. These constraints represent limits on the fixed factors of production, in the land area available on the farm and the fertility of the soil. There are four sub-groups of the real constraints:

1. <u>Land Utilisation</u>

   The land requirements constraints group (a) comprises seven rows of unity coefficients showing for each time period within the crop's cycle that land is required by each crop. The inequalities ensure that in any time period the area of land required is less than or equal to the total farm area (see Appendix X).

2. <u>Irrigation</u>

   The irrigated land requirement constraint (c) confines the area under irrigated crops to less than (or equal to) the maximum area currently irrigable.

3. <u>Crop Rotation</u>

   The rotational cropping constraints group (b) confines the selection of crops in such a way that only a workable crop rotation can be selected. For example, these render as infeasible a solution where the whole farm could be under first year cereals (since this could not be sustained over several seasons). Thus, the static model can select crop rotations which are stable over time. The practice of undersowing all clover crops with cereals or ryegrass is included in the rotations system because the interdependence between the area of host and clover crops imparts a fixed two-year sequence on land selected for clover. Its high value to the cropping system is in terms of income (from the seed crop), soil fertility replenishment, as a source of pasture grazing and hay, and its low establishment cost.

4. Land Fertility

The fertility constraint (d) assigns coefficients to each crop activity to reflect the relative changes in soil nutrients and structure which can be attributed to growing a specific crop[15]. Where wheat is grown in successive years on the same land even with adequate artificial fertilizer applications, wheat yield typically declines as a result of impoverishment of soil fertility and increasing pest incidence. On the opposite hand legume crops, such as clovers, lucerne, beans and peas have a rapid positive enriching effect on soil nitrogen levels. The fertility constraint defines these relative differences and ensures that the system chosen maintains or improves fertility, rather than allowing a solution for short-run profit at the expense of declining longer-run fertility.

15 Coefficients are from personal communication from Frengley(1978).

<u>3.4.2 The Artificial Constraints</u>. Farm policy states as a cropping objective that one third of the total area is to be under pasture seed crops and at least one third to be under cereals. Two constraints are used accordingly (sub-matrix (e)).

A second group of artificial constraints are imposed to restrict the amount of high quality feed that is transferred to low quality supplies. If no restriction is specified the first quality feeds could then be transferred over time (see 3.2.2. (2) Feed Supply). A problem arises in that the feed value of forages left past their prime declines sharply as digestibility and palatability are reduced. Feed values of carryover forage crops would, if allowed, have to be re-estimated and little data on crop deterioration are available. However, with flexibility on some farms transfer of high quality feed to low quality uses does occur and should, therefore, be allowed. The transfer of top to lower quality feed (n) in any period is therefore constrained to be at most equal to low quality feed demand (i) in the same period. In this way, if high quality feed is not utilised in any period to meet demand for high quality feed, then transfer can occur as long as the quantity concerned can be consumed before the end of the following period in a quality two use. Any excess low quality feed can be carried over to the following time period or sold.

3.4.3 Accounting Constraints. These constraints are aimed at balancing the demand for each input generated across all productive (and some non-productive) activities (sub-matrices f and g) with a supply of inputs (k and l) monitored and costed in the input supply activities. Corresponding to each of the input supply activities listed above (see section 3.3.2) is one input demand constraint. Each demand constraint, with the exception of total energy, has the inequality set at less than or equal to zero so that the level of supply of any input is at least equal to the on-farm demand for it.

Feed supply constraints operate slightly differently since in each considered time period feed demand comprises three elements[16]; consumption (j), sales (m) and surplus transferred (o, representing demand in other periods or of other qualities) and supply comprises three factors, farm grown (h), purchase from off-farm sources (m), and transfers in from other periods and qualities (o). These demand and supply factors for feed are accounted in two qualities (see Appendix III) and over seven periods (see Appendix X).

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[16] There is also a fourth option implicit and that is feed which remains uneconomic to utilise or sell is merely left in the paddock and would be ploughed in before replanting. Periodic feed supply and demand coefficients are derived in Appendices III and VII.

3.5 The Objective Function

In keeping with the assumed farm objective of maximised profit, the model objective function represents revenues accruing to productive activities (q) and the variable and semi-fixed costs associated with input supply activities (r). Farm net revenue is calculated by subtracting the variable and semi-fixed costs from the revenues (in the model, costs are assigned negative values whilst revenues are given positive values).

The revenue which will result from the adoption of a cropping activity will itself be the product of three elements; yield per hectare, the number of hectares grown and the price per tonne which the farmer will receive. Since the model solution determines the number of hectares grown, the objective function merely records the per hectare revenue, equal to the product of assumed levels of yeild and price received.

The costs which are incurred by the input supply activities are purely a function of the amount purchased and the purchase price paid. Again the model solution itself determines the amount required to be purchased and the objective function coefficient is simply the unit price of the input. For semi-fixed (machinery) supplies, the unit price is replaced by the exogenously calculated unit cost (fixed costs per year or variable costs per hours use).

Lastly amongst the accounting constraints is one which monitors the use of energy across all inputs purchased. In this row vector, direct and indirect energy inputs are treated as being homogeneous in terms of megajoules. The constraint is not binding and unlike the others in this category the right hand side merely assumes the sum value of all energy used.

3.6 Summary

Data sources described are found to suit a programming approach rather better than a systems simulation model. It is anticipated that improving the data for use in a simulation approach would be too time-consuming. Previous studies have shown that comparable analytical requirements have been met with a programming approach. In a study specific to the Lincoln College mixed cropping farm, programming can adequately incorporate the essential farm charactertistics which influence the behaviour of the farm system to change. Such characteritics are inflexibility of husbandries (so that a crop is usually grown in one of a few well-proven ways), the lumpiness of capital and selection of crop and stock activities based on an objective for high net revenues (assumed to be consistent with the model's objective of maximised net revenues).

Choice within the programming methods is narrowed to a linear or non-linear version. The linear version is consistent with the major features of farm practice and environment. For example, as a small producer, prices of inputs and outputs are exogenously determined; the farm itself exhibits no visible economies of scale.

A linear programming model is chosen, and is specified using available data.

CHAPTER 4

VERIFICATION OF MODEL PERFORMANCE

In the use of models, the confidence which can be placed in generated output will depend upon the accuracy with which the model copies the essential behaviour of the real system. As a check, tests are carried out to ensure the model is a valid representation of the system. These inevitably involve comparisons showing the degree to which the model can mimic a situation which occurred in the past. Given set conditions from the past, if the indicators of performance are similar in the test model output to those which were actually observed in the real situation, the model can be deemed an adequate representation of the behaviour of the true system. The methods used to check these indicators against the real observations are called validation procedures.

4.1 Model Validation

Two separate tests of performance are used to ascertain the validity of the model developed for this study. The first stage is to ensure that the input-output coefficients in the model closely resemble the real coefficients. This is done by constraining the model to the land use pattern of a previous season to determine the aggregate requirement for each input and the production of output predicted by the model. These 'predictions' are compared with the already known input and output data from that year and generally, the closer the comparison, the more acceptable the model is shown to be.

Given that the technical input-output coefficients that can be checked in this way are sufficiently accurate the second stage checks that the model will optimise the productive activities in the same pattern as is observed on the farm. If this occurs the model makes the same decisions to maximise the objective functions as the farm manager has in the past to attain his goals and the 'predicted' model system will resemble closely the observed farm system. When this stage is reached the model is assumed to be reasonably established as a valid copy of the real farm[17].

The data used in the validation procedures are principally derived from the Farm Bulletins and from farm accounts. Limitations in these data preclude exhaustive validation over several years of farm operation.

4.1.1 Validation of Technical Coefficients. The selection of cropping activities is artificially constrained and bounded to reproduce the land use pattern of the 1976-77 season shown in Table 4.1. An estimate of total diesel

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17 Validation strictly holds only within the bounds tested, that is, accuracy can only be proven in respect of a certain set of conditions for which system behaviour is known. It does not necessarily hold for other sets of conditions (such as high energy prices) which cannot be tested for lack of known data. Under the circumstances, the proposed validation is the best that can be done.

TABLE 4.1

The Mixed Cropping Farm Land Use Patterns For

1976-77 and 1977-78

1976-77		1977-78	
Crop	Area(ha)	Crop	Area(ha)
AWHEAT 1A	42.6	AWHEAT 1A	17.6
SWHEAT 1A	14.6	AWHEAT 1B	21.5
BARLEY 1A	4.9	SWHEAT 1A	10.2
BARLEY 1B	12.8	BARLEY 1A	16.0
TICK BEAN (Spring sown)	2.8	TICK BEAN (Spring sown)	6.6
SEED PEAS	21.7	SEED PEAS	6.1
FREEZING PEAS	26.2	FREEZING PEAS	17.6
TAMA RYEGRASS (Intensive)	4.9	TAMA RYEGRASS (Intensive)	9.1
MANAWA RYEGRASS	5.3	MANAWA RYEGRASS	5.3
GREENFEED OATS	16.0	GREENFEED OATS	16.0
WH.CLOVER (Irrigated)	17.6	WH.CLOVER (Irrigated)	9.4
WH.CLOVER	16.5	WH.CLOVER	32.8
		LUCERNE	5.2
		KALE (for seed)[a]	4.0
		FODDER BEET (for seed)	8.0

[a] These crops are grown under contracts which have only been available in alternate years. The contracts pre-fix the acreage to be grown, and there is no flexibility once the contract has been agreed.

fuel used for productive (and miscellaneous) purposes is from farm data reported by Clark (1978). He recorded that 13,231 litres of diesel fuel were used over this season for productive activities. The model estimates this value to be 13,167 litres, 0.5 percent below Clark's figure.

Diesel fuel used in maintenance and general farm work (i.e diesel other than that attributable to cropping cultivations, spraying, mowing, harvesting and irrigation shifting, is not covered in farm data, or the model, and thus is not checked. (In total, Clark estimates this to be only six percent of total diesel fuel use in 1976-77). Petrol used in cartage off the farm cannot be validated either since no record of this usage has been kept by the farm[18].

The selection of productive activities is subsequently altered and artifically constrained to reproduce the land use pattern of the 1977-78 season. Table 4.2 compares actual with model estimates of the physical input requirements for fertilizers and sprays for the season ended January 31st, 1978[19]. The divergence between estimates is divided by the actual use elements and is thus expressed as a percentage error of the model estimate from the actual.

Machinery input requirements are not easily verified since no account of actual machinery hours is recorded. However, for tractors and combine harvesters, the mixed integer

[18] Clark's survey necessitated checking fuel data with the model for 1976-77. No other physical inputs are checked for this season, the preference being to compare 1977-78 season model use with actual use, because of more complete data in the latter year.

[19] 'Season' refers to inputs used for that season's crops only (to be compatible with the model's 1977-78 season), not including those purchased or used during the season for subsequent crops.

TABLE 4.2

Actual and Model Estimates of Spray and Fertilizer Requirements, 1977-78

Input	All Sprays	Flow-master Super	Turnip & Rape Super	Pea. Lucerne Mix & 30% K Super	Nitrogen Super	Nitrogen
Units:	litres	tonnes	tonnes	tonnes	tonnes	tonnes
Model Use	1379.6	16.2	4.0	14.95	10.1	8.17
Actual Use[a]	1299.7	15.61	4.0	14.95	10.6	8.28
Model Error (%)	+6.5	+3.5	0	0	-4.7	-1.4

[a] Data compiled from Farm Bulletins and adjusted for season

routine fixes requirements at three tractors and two combine harvesters, equal to the current (1978-79) complement of machinery.

Similarly, no separate accounts are kept of annual hours usage of implements, truck mileage or irrigation usage which makes validation of these inputs in physical terms impossible.

The cropping system is maintained at the 1977-78 season pattern to compare some financial parameters. Comparison is based on farm accounts data to which several adjustments are necessary, for the following reasons:

1. The financial year does not coincide with the cropping year and in annual accounts, revenues outstanding from the previous season and costs incurred for the following season's crops are included. These items have to be removed before comparison can be made with model results.
2. Whilst prices in the model are set for January 1st, the actual prices that the farm will have to pay for inputs in the beginning of the crop season will be modified by inflation and the prices received for farm output will be modified by market movements. Accounts data include the price at the time of payment, and this may cause some apparent degree of model error.
3. It is necessary to remove the effect of stock accumulation or consumption occurring over the year to derive expenditure on inputs actually used. This is not possible because of insufficient detail within the accounts.
4. Accounting procedures differ in the model over semi-fixed capital items. Interest and depreciation which are aggregated over all capital items cannot be compared with the model, since interest payments are embodied (in various different ways) in machinery

costs as separated activities.

Given the limitations of using the farm accounts as a means of comparison the following table shows selected parameters from the farm accounts which are less prone to inaccuracy (i.e. which can be more reliably adjusted for the model season and method). The variation of divergence between model and actual can be expected to be wider for financial comparisons because, in the extreme case, inaccuracy of the estimates of physical inputs is likely to be compounded by inaccuracies in pricing. Bearing in mind the pitfalls in using accounts data as a yardstick for model validation, Table 4.3 shows a comparison of some financial parameters.

Table 4.3

Comparison of Farm Accounts with Model Output

(year ended June, 1978)

Expenditure Item ($)	Model Output	Farm Accounts
Diesel Fuel	1815	2100[a]
Freight / Cartage	1468	1335
Cropping Costs (sacks, dressing and all seed)	11082	11386
Revenue from Cropping	104313[b]	96695
Revenue from Grazing	9356	10460

[a] $2260 was the expenditure on all diesel used but this is including that used in non-productive uses such as drain cleaning, roadside topping. In Clark's study, the fuel used on those tasks was about six percent for the previous season and thus productive use of fuel may account for $2100 of costs.

[b] Revenue from cropping includes $18,440 from the seed crops of fodder beet and kale.

Accepting that problems of accuracy of comparison exist, the Farm Accounts do give an indication that the model performs within an acceptable range of error. The most pessimistic result is a 14 percent error in diesel expenditure.

4.1.4 Validation of the Objective Function. The artificial bounds imposed to restrict crop land use to previous season's in the earlier stages of validation are removed. The optimal enterprise mix can now be located for the 1977-78 season and compared with the actual cropping and stocking that occurred in that season. The Farm Supervisor was asked to comment on the differences which emerged between the profit maximising model and the farm. The differences are shown in Table 4.4.

TABLE 4.4

The Optimal and Observed Farm Systems 1977-78

Crop Group	Model Selected Area (Ha)	Actual Area (Ha)
Cereals	81.4	65.3
Legumes (peas and beans)	24.2	30.3
Pasture Seeds	62.0	66.8
Fodder crops (winter greenfeed)	17.6	16.0
Miscellaneous[a]	12.0	17.2

[a] Miscellaneous crops include lucerne, kale and fodder beet grown for seed on contract.

The overall system is generally close to that of the optimum shown by the model. In order to reach the optimal system, only 7.6 percent of the total farm area has to be transferred from one crop to another (discounting the winter greenfeed which only competes for land in the slack winter period). The farm supervisor had noted poor returns to previous seed pea crops and intended to remove this activity from the cropping system entirely. He also agreed with the relative returns to cereals, especially in the growing of barley, the returns from which are lower than autumn sown cereals and which it would seem profitable to exclude. Despite this, the supervisor could see little change in the near future to the farm system, apart from the exclusion of seed peas which leaves 5.6 percent of the land area as the discrepancy between the model (and its given objective function) and the observed farm system.

The divergence that does exist between the modelled profit maximisation solution and the actual farm system reflects the model's inability to account for all the factors inherent in the actual objective function (besides profit). An explicit treatment of risk may have benefitted the model by reducing this discrepancy but whether the additional costs of such an exercise outweigh the benefits is uncertain. Generally, it seems that without explicit incorporation of risk, the model provides an acceptable degree of accuracy when tested against recent farm data.

Within the crop groups, changes could also be made so as to increase the farm net revenue. Optimal cereals production would involve moving towards first crops of autumn sown, conventionally cultivated wheat on 39 per cent of the farm. Currently, any other cereals crop, if grown, is not maximising farm net revenue. A similar movement towards white clover is indicated for pasture seeds production because of the higher average returns attained over the past few seasons than the alternatives, the ryegrass seeds. For miscellaneous crops, when contracts are available for freezing peas, tick beans, fodder beet seed and kale seed the contracts are always fulfilled. If contracts are not available on these crops, the lower returns to the remaining miscellaneous crops (which include pastures, fodder crops and seed peas) suggest that the activities that would gain land would be the more productive cereals and pasture seed groups.

Whilst the area of crops is reasonably comparable between model and actual situations, the quantity of sheep-days grazing is less so. However, generally at prevailing prices, both the model and the farm itself agree that agistment and contract grazing sales are more profitable than the marginal farm-owned breeding and fattening sheep flocks.

Thus, in general, the production system observed on the farm is mimicked by the model. The predicted use of inputs, where adequate comparisons could be made, are within five per cent of the observed system, and where less accurate financial data are compared, the model seems to perform to within a ten percent error margin on parameter predictions that could be tested. A trade-off between simplicity and the expense of greater accuracy has to be made. As a result of this, the degree of accuracy attained is not sufficient to pinpoint with confidence absolute levels of specific parameters under varying extreme conditions and individual results should be treated accordingly with caution.

The validation processes can not objectively assess and guarantee the magnitude of errors likely when the model is used experimentally and are not expected to do so. It can be said however, that the model seems to behave in a way consistent with the mixed cropping farm during tests using historic data. It should also be noted that whilst some error is inevitable in particular elements (due to incompatible accounting methods, for example) the degree of errors that have been determined during validation are not likely to detract from the conclusions of the study overall, where the objectives are to identify trends of change in farming activity caused by divergent policies. For the purposes for which it is built, the model presents, as far as is discernable, a valid representation of the behaviour of the mixed cropping farm.

4.2 Summary

Model validation tests first ascertain the accuracy of the model input-output coefficients by comparing 'predicted' use with the observed aggregate use in previous years. Subject to problems of comparability of historic data the inputs of sprays, fertilizers and diesel fuel measured in physical terms are within seven percent in each case. The ownership of tractors and combine harvesters is similar to that observed on the farm. However, not all inputs could be compared on this basis because of the absence of observed data (especially on hours of machinery input).

Aggregate cost and revenue data, where reasonably compatible, are compared with model results for a previous time period. At the most pessimistic, diesel fuel expenditure is in error by an underestimate of 14 percent.

The model objectives are tested in conjunction with the validated input-output and costing coefficients. Constraints to predetermine crop selection (used in the above validation tests) are removed and the model criterion of net revenue is allowed to produce an optimal selection of crops. When compared with the observed farm system in terms of the areas under principal crops, the predicted cropping pattern is in error on less than eight percent of land used.

The margins of error shown when the model is applied to conditions existing in the past suggest the validity of the model. Given this assessment of validation, the model is used experimentally on a different set of conditions related to changed energy availability and prices that may occur in the near future.

CHAPTER 5

ANALYSIS AND RESULTS

The static linear programming model is used to simulate changes at the farm level which may result from restrictions on the quantity supply of fuels and, separately, from increases in the world petroleum price. In the analysis of the latter scenario, increases in the model price of refined fuels are used to simulate real increases in world petroleum prices. Both pricing and rationing scenarios apply to diesel and gasoline used only for productive purposes[20]. The rationing scenario operates under constant 1978 prices.

Early results show that the model farm would reduce contracting out activities rather than change the cropping system. This enables approximately 20 percent of the base model farm's fuel consumption to be cut without any change in the production system under either scenario. Fuel use in contracting is a cushion against the shocks of initial changes in the supply conditions of fuel. To determine

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[20] "Productive" purposes apply to the use of fuel where it can be attributed as a direct cost to a specific enterprise. It is assumed that the fixed, non-enterprise related uses of fuel (e.g. drain clearing, hedge trimming) are exogenously determined and will not vary with the scenario presented.

the changes in cropping more clearly, the contracting activites are therefore omitted in subsequent analysis.

Further omissions from the model version used for analysis of alternative scenarios are the two lucrative contract seed crops, fodder beet and kale. Contracts were not available for the 1978-79 season. The changes in the farm system as a result of releasing the land under these two crops, omitting contracting out activites and including extra land available[21], have caused the base model solution (see Table 5.1) from validation to alter quite significantly. The alterations lead to a change in cereals area from one third of the farm to two thirds[22]. These changes from the validation model occur because it is necessary to examine more closely the changes applicable to the farm system existing in the 1979-80 season.

In this chapter the results of progressive increases in rationing levels and fuel prices are shown separately and are then compared for discussion at a later stage.

5.1 The Effects of Rationing Farm Fuel Supply

The base model is solved for successive fuel ration-

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21 The mixed cropping farm acquired an extra 35 hectares which increased farm size to 213.5 hectares after neighbouring land became available in mid 1978.

22 This change would imply that, in a year when the contracts for fodder beet and kale seed crops were not available, such land would most profitably be used in cereals production.

ing cuts by a parameterisation routine. This technique takes 'total fuel requirements' and reduces its value in five percent steps, resolving the whole linear programming matrix for each step. In this way fuel supply is rationed down to 50 percent of the 1978 base model level. The results of a rationing policy under constant prices are shown in Table 5.1

5.1.1 Changes in Farm Production Systems. As fuel supplies to the farm are reduced, the optimal production systems selected which maximise farm net revenue change through four distinct phases, shown in Figure 1. The order in which these phases occur is important since it shows the energy reduction alternatives ranked by their effects on farm net revenues. The first alternatives adopted are those which reduce farm income by the smallest amount, that is, fuel which is used with a low marginal return is cut before those uses with a high marginal return. Whilst in the first phase each percent fuel cut is achieved through a net revenue reduction of $158 on average, by the last phase, a one percent cut causes a loss of income of $789.

Fuel reductions up to, but not including the 20 percent level induce cropping changes that alter the balance of land area under cereals relative to break crops (the cereals : break crop ratio falling from 2 to 1 during this first phase). Land transfer out of cereals production is

TABLE 5.1

The On-Farm Effects of a Policy to Reduce Farm Fuel Use by Rationing.

REDUCTION IN FUEL USE	%	Base	5	10	15	20	25	30	35	40	45	50
AWHEAT 1A[a]	ha	71.2	78.2	89.7	101.3	106.5	106.5	88.8	58.4	28.1	0	-
AWHEAT 2A[b]	ha							17.7	48.1	78.4	106.2	98.5
AWHEAT 2B[c]	ha							0.25	0.25	0.25		
BARLEY 1B[d]	ha	71.2	57.2	34.1	11.0	0						
FREEZING PEAS	ha	14.3	14.3	14.3	14.3	14.3	4.9	0				
TICKBEANS - Autumn sown	ha	7.7	7.7	7.7	7.7	0						
GREENFEED OATS	ha	85.5	71.5	48.4	25.3	10.2	0					
WHITE CLOVER (irrigated)	ha	49.1	0									
WHITE CLOVER	ha	0	56.2	67.7	79.3	92.7	102.1	106.7	106.7	106.7	106.2	98.5
IRRIGATED LAND	ha	63.5	14.3	14.3	14.3	14.3	4.9	0				
LAND UTILISATION[e]	%	72	73	74	74	75	77	79	79	79	78	73
RATIO CEREALS : BREAK CROPS		2.0	1.7	1.4	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
TOTAL ENERGY INPUT	GJ	1506	1440	1391	1342	1301	1267	1246	1229	1213	1190	1105
TOTAL TRACTOR USE	'00 hours	11.6	10.3	9.3	8.3	7.6	7.0	6.3	5.7	5.0	4.4	4.1
TOTAL COMBINE USE	hours	254	258	266	273	272	279	282	282	282	280	260
SPRAYS	GJ	177	188	205	223	241	254	270	285	299	311	289
NITROGEN	tonnes	5.92	4.76	2.80	0.90	0		0.02	0.02	0.02	0	
COMPOUND FERTILISERS	tonnes	65.8	61.5	54.2	47.0	42.6	40.1	42.3	46.1	49.9	53.1	49.3
DIESEL FUEL	'000 litres	11.97	11.33	10.74	10.16	9.58	8.97	8.32	7.63	6.94	6.26	5.65
PETROL FUEL	'000 litres	3.08	2.98	2.81	2.64	2.46	2.32	2.22	2.16	2.09	2.02	1.88

[a] A first cereal crop of autumn sown conventional wheat.
[b] A first cereal crop of autumn sown reduced cultivation wheat.
[c] A second cereal crop of autumn sown reduced cultivation wheat.
[d] A second cereal crop of conventional spring barley.
[e] A 100 percent land utilisation coefficient represents the total land area being utilised in all periods within the year.

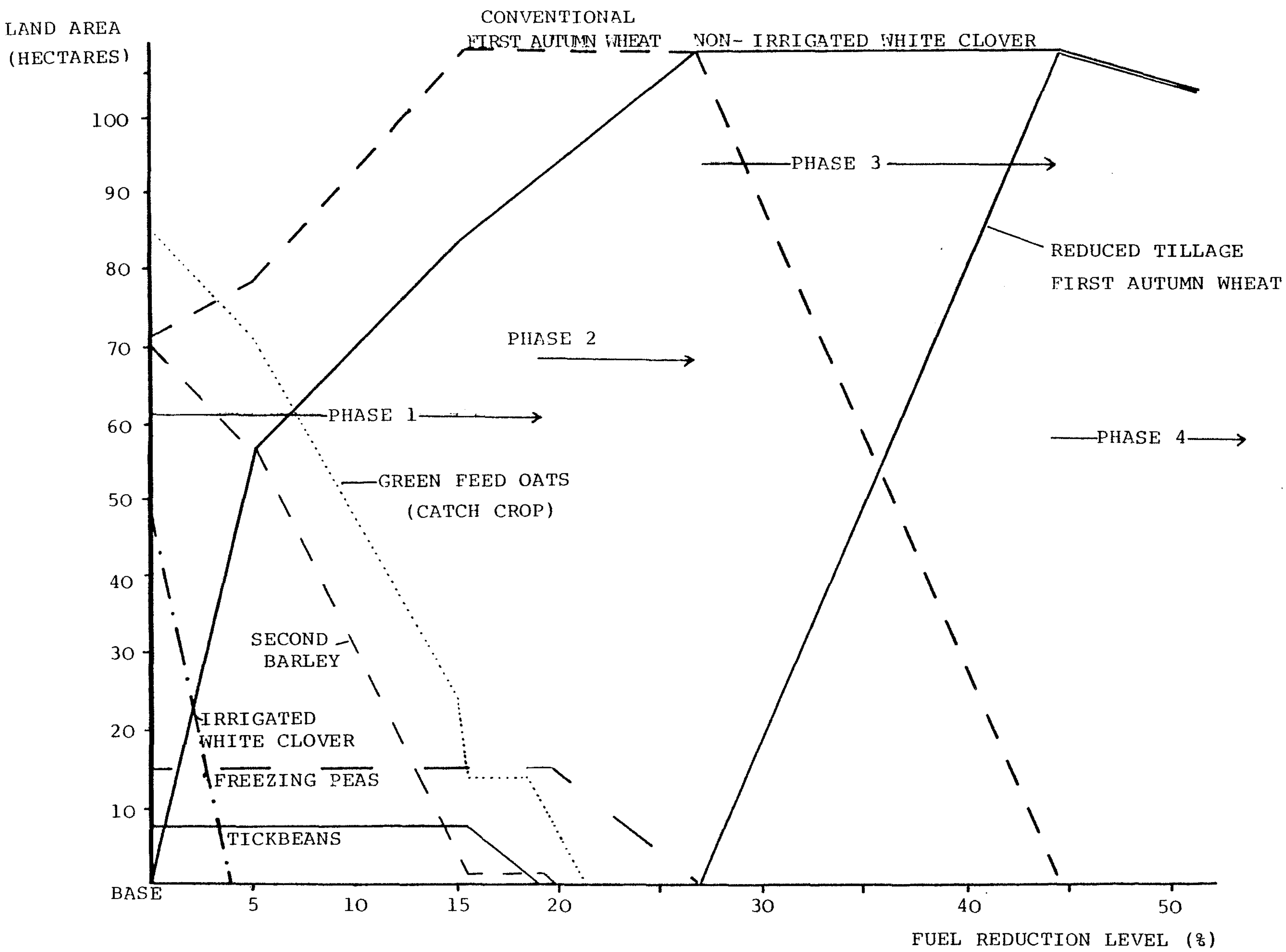

Figure 1 : Fuel Reduction[a] and the Effect on the Farm Production System.

[a] 'Fuel Reduction' is used separately from 'Fuel Rationing'. A reduction of fuel use, however implemented, would have this effect on production.

effected by reduction of the area under a second cereal crop (conventional spring barley) passing the land released in equal proportions to a first cereal crop (conventional winter wheat) and to a break crop (white clover) until at the 20 percent level both crop groups each occupy one half of the total farmed area. Implied in this result is a shortening of crop rotation cycles, from a three to a two year system. The two year system remains stable for all rationing levels tested at 20 percent and above.

Specific crops which leave the optimal solution during the first phase are (in order) irrigated white clover (which passes to non-irrigated white clover production), second year barley and autumn sown tickbeans. Winter greenfeed oats is steadily reduced in area. At the end of the first phase the system of production remaining is a two year rotation of first year autumn wheat, conventionally grown with undersown non-irrigated white clover and a small area of contract freezing peas. About ten hectares of the land used for contract peas, sown in the spring, is preceded by a winter catch crop of greenfeed oats, sold for grazing between mid June and mid August.

The second phase occurs at the 20 and 25 percent rationing levels. With a stable two year rotation, fuel savings in this range are made by reorganisation within the break crops category. Contract freezing peas pass out of the solution, the land being transferred to the principal break crop of white clover. The area of winter fallow before the pea crop planting thus disappears, and with it the greenfeed oats catch crop, leaving early and late season grazing of white clover as the only significant supply of forage on the farm. The role of sheep in this mixed system tends to decline as production concentrates around cropping.

The third phase occurs above 25 percent rationing and up to about the 45 percent level. The farm system adjusts to reduced fuel use over this range by altering the method of producing the crops, in the stable rotation, wheat and white clover. Whilst the model only includes two methods of white clover production (irrigated and dryland production, a substitution occurring in the very first stage of rationing) several alternative production methods have been included for wheat. During this phase, the requisite fuel economies are made by adopting one of these; minimal tillage practices for wheat, a husbandry which leads to lower costs per hectare (through lower cultivation[23], and thus machinery, fuel and labour requirement) and lower yields[24]. As land under conventionally

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23 See Appendix II

24 Yield reduction as a result of adopting reduced tillage methods is assumed at 18 percent (Steele, 1978). This may err on the pessimistic side when compared with overseas studies. In some trials under certain soil conditions, crop yields of reduced cultivation cereals actually increased over conventional crops in work carried out by the National Institute of Agricultural Engineering in the U.K. (A.D.A.S., 1978).

cultivated autumn sown first wheat is successively transferred to minimal cultivation practices, the white clover crop area remains unchanged.

The fourth phase applies to fuel reduction of 45 percent and above. Wheat and white clover crop areas are maintained in balance throughout as the profit maximising system and fuel saving can only be effected by reducing the total cropped area. It appears rational for the farm manager to allow land to fall out of production rather than adopt any other system included in the model because fuel (which is the limiting resource) is being used in such a way that its marginal addition to total net revenue is greatest with land becoming idle under a wheat/white clover system. At 45 percent rationing under a low energy input sheep activity total net revenue would be reduced by $191.88[25] if 20 hoggets were included in the solution (and, of course the activities necessary to supply sufficient feed). It is more profitable to the whole farm if land passes out of production.

5.1.2 Changes in Input Use. Movements in the aggregate farm use of inputs are presented graphically in Figures 2 and 3[26].

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25 From reduced cost data produced by the model.

26 Interestingly, in the base model, the indirect energy input from sprays is greater than any single fertiliser nutrient (but is less than the fertiliser total). This is contrary to common opinion which states nitrogen fertilisers as the highest indirect energy input. To confirm this, the farm in 1978 would have actually used $7195 worth of sprays and only about $1450 on nitrogen which after applying Dawson's MJ/$ coefficients from Appendix IX gives 188 GJ of sprays opposed to 168 GJ of nitrogen.

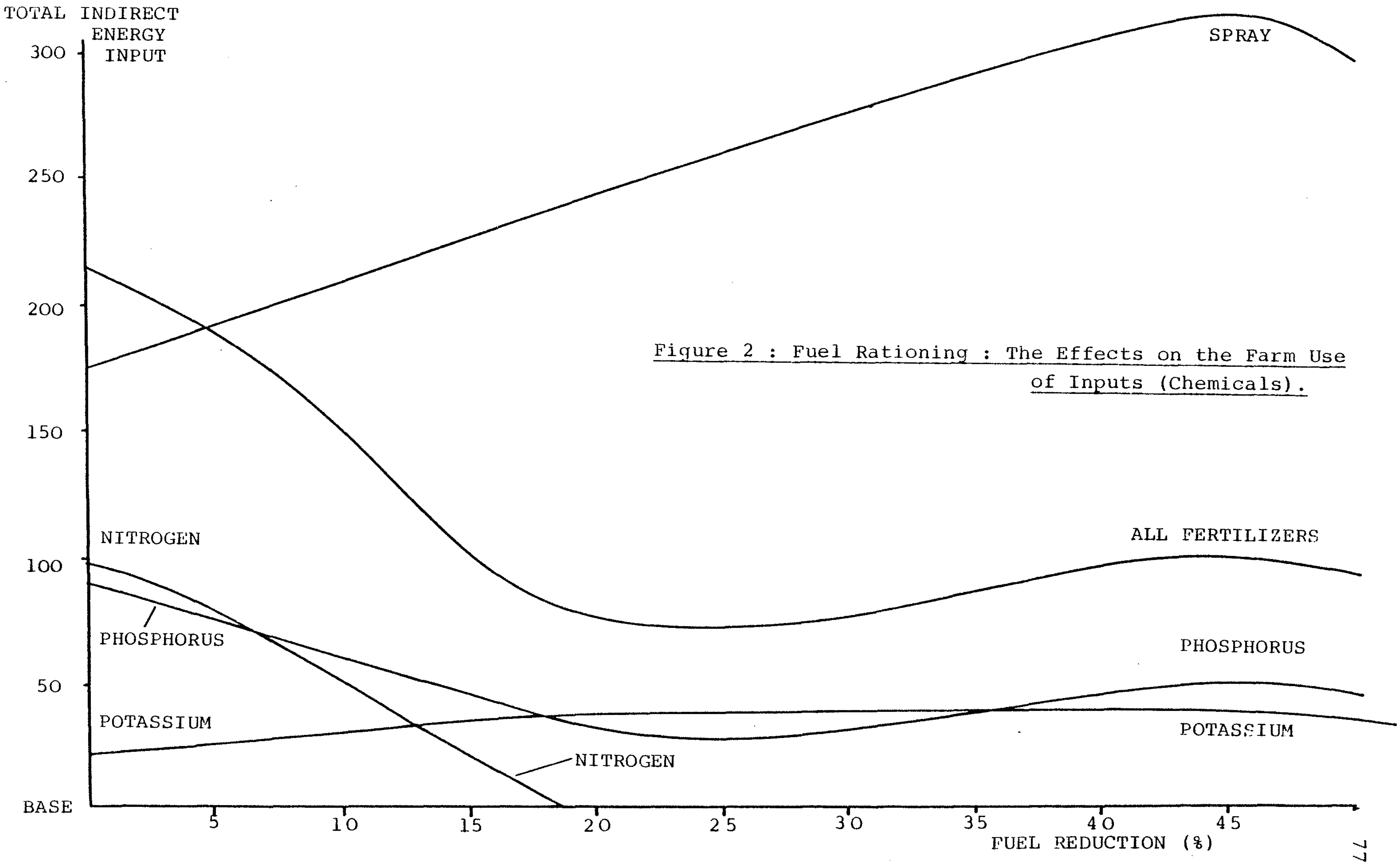

Figure 2 : Fuel Rationing : The Effects on the Farm Use of Inputs (Chemicals).

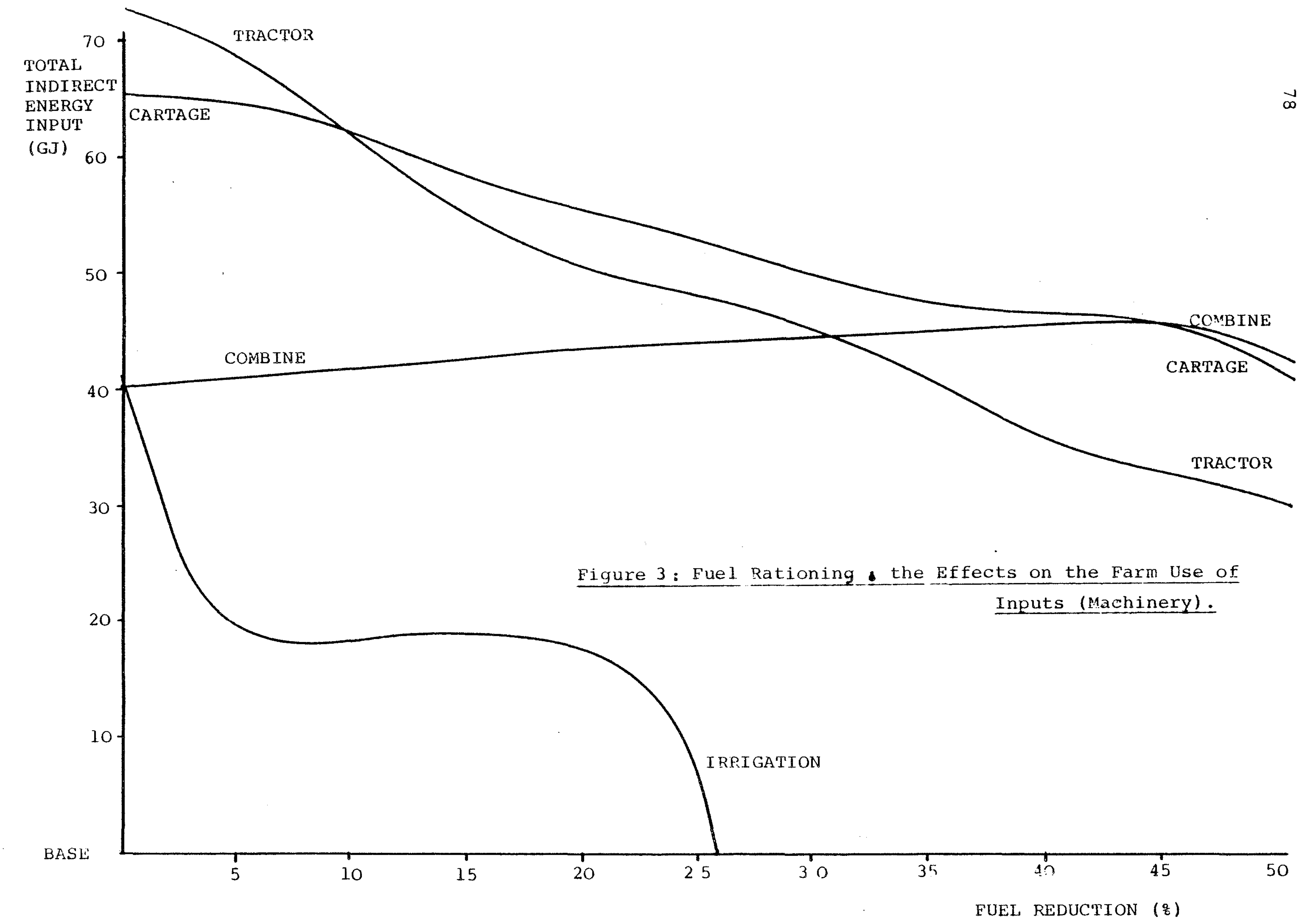

Figure 3: Fuel Rationing & the Effects on the Farm Use of Inputs (Machinery).

Most noticeable amongst the chemical inputs is the suppression of nitrogen use (both in straight nitrogenous fertilizers and in nitrogen superphosphates) and the growth in sprays usage. Nitrogen input at higher rationing levels is restricted wholly to that fixed from the atmosphere by bacteria which live in symbiosis with white clover[27]. Phosphorus application drops, then rises again at levels above 25 percent rationing. Potash application rises with increased clover area and remains stable above a 20 percent cut. Sprays use increases consistently as a side effect of both reduced cultivations and increased clover areas which demand higher applications in weed and insect control.

Machinery use varies between machine types. Use of irrigation plant on the farm is dramatically reduced at low levels of rationing; fuel saving is partly attained through reduced demand for irrigation towing. Demand for tractor hours work is also diminished because of the opportunities to substitute to crop systems requiring lower cultivation. Use of combine harvesters however, rises gradually as the harvested area of white clover increases due to the slower work rate of the header over clover. Cartage requirements fall as the high physical volume of cereals output falls and the low (by weight) yielding clover area rises.

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27 Studies in the U.K. indicate that where soil pH, potassium, phosphates and trace elements are not limiting, the potential is for white clover to contribute between 100 and 300 kilograms of nitrogen annually across several sites (and thus soil types (in J.M. Day, 1977)).

5.2 The Effects of an Increasing World Petroleum Price[28]

In the short run, a rising world petroleum price will lead to increased retail prices of fuels only. Subsequently, other industrial sectors will experience rising fuel costs and some more than others will be able to pass on such increases in higher prices for sectoral outputs. Agriculture as a purchaser of the products of other sectors is in the longer term likely to experience such "second round" price increases which will act to further increase the cost of non-fuel inputs consumed on the farm.[29] The magnitude of the "second round" effects on the prices of all farm inputs is estimated in Appendix IX

During the analyses of the effects of high oil prices, it is assumed that, unlike other sectors, New Zealand farming is not able to pass on cost increases through higher prices to consumers: prices received by farmers therefore remain constant. Section 5.5 examines the sensitivity of farm incomes to output price changes.

Fuel price increases in steps of 100 per cent over 1978 levels are introduced, and the resulting

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[28] Since this scenario represents an effective fuel price increase, it can be viewed as having the same effect as a tax on fuel use.

[29] Although fuel price increases occur rapidly after increased oil prices the subsequent readjustment of all other prices occurs at some time after this. The lag in time before other prices increase is of uncertain length. To distinguish these effects "short term" refers to the more partial effects whereas "long term" refers to the full equilibrium effects on prices.

TABLE 5.2

The On-Farm Effects of Policies Increasing Petroleum Fuel Prices

FUEL PRICE INCREASE (%)	SHORT RUN	BASE	200	600	-	1000
	LONGER RUN	BASE	200	600	900	-
AWHEAT IA	Ha	71.2	71.2	106.5	106.5	106.5
BARLEY IB	Ha	71.1	71.1	0.5	0.5	0.5
FREEZING PEAS	Ha	14.3	14.3	14.3	14.3	14.3
TICK BEANS (SPRING SOWN)	Ha	7.7	7.7	7.7	2.8	0
GREENFEED OATS	Ha	85.4	85.4	14.8	14.8	14.8
WHITE CLOVER (IRRIGATED)	Ha	49.1	0	-	-	-
WHITE CLOVER	Ha	0	49.2	84.5	89.4	92.2
IRRIGATED LAND	Ha	63.5	14.3	14.3	14.3	14.3
LAND UTILISATION	%	72	72	75	75	76
RATIO CEREALS:BREAK CROP AREA		2.0	2.0	1.0	1.0	1.0
TOTAL ENERGY REQUIREMENT	GJ	1506	1470	1320	1310	1305
TOTAL TRACTOR + IMPLEMENTS USE	'00 Hours	11.6	10.9	7.8	7.8	7.7
TOTAL COMBINE USE	Hours	254	254	276	274	272
SPRAYS	GJ	177	177	231	237	240
NITROGEN	tonnes	5.92	5.92	0.04	0.04	0.04
COMPOUND FERTILIZERS	tonnes	65.8	65.8	43.6	43.7	43.8
DIESEL FUEL	'000 litres	11.97	11.68	9.89	9.74	9.65
PETROL FUEL	'000 litres	3.08	3.08	2.57	2.51	2.48
FUEL REDUCTION ACHIEVED	%	0	2.0	17.3	18.7	19.5

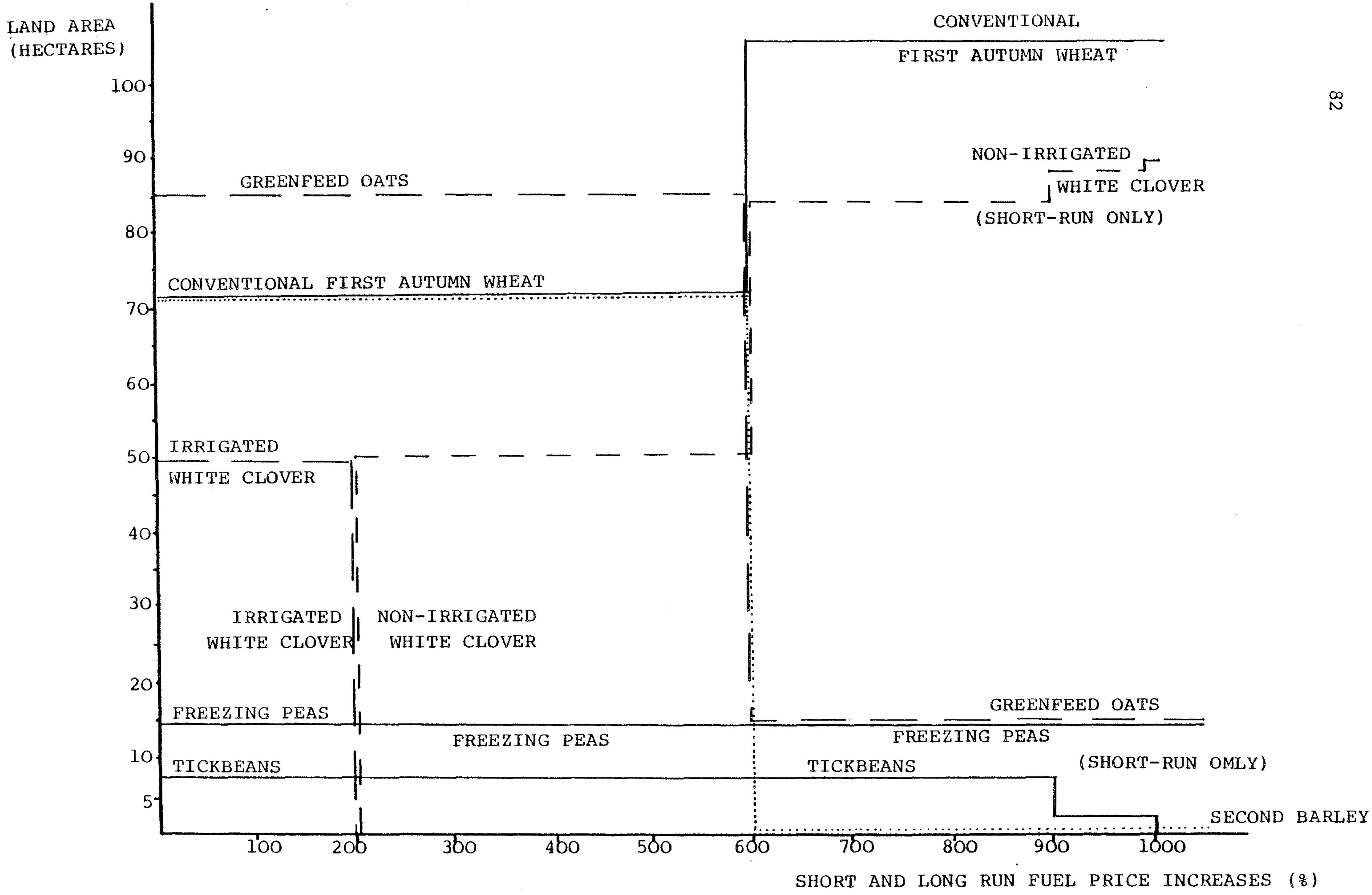

Figure 4 : Fuel Price Increases and the Effects on the Farm Production System.

solutions are shown in Table 5.2 and digrammatically in Figure 4. Such large steps are used because change in farm production was found to be very insensitive to small fuel price increases. Table 5.2 shows only the results of simulated price changes which lead to changed farm systems (at 200, 600, 900 and 1000 percent). Price increases between these solutions adopt the same system of production as the preceding changed solution (i.e. the farm system is the same at a 400 percent fuel price increase as at the given 200 percent solution.

<u>5.2.1 Changes in Farm Production Systems</u>. For the longer run analysis, the changes in production systems are identical to those occurring in the short run throughout price increases to 800 percent of 1978 price levels. At about a 200 percent increase, the model farm removes irrigation from 49 hectares of white clover, resulting in a seed crop which averages 11 percent less yield than when irrigated. Fuel use is reduced by the saving in tractor hours required to move the angletow irrigation system. Despite the farm having to meet the fixed costs associated with the irrigation plant, use of the angletow system is reduced from 63 hectares requiring water to 14 (see Appendix IV on irrigation costs).

Fuel price increases of around 600 percent lead to changes in the farm system which are similar to changes during the first phase of rationing. The cereals to break crop ratio falls from 2.0 to 1.0 with land use passing from a second cereals crop of barley equally to expand areas of first year autumn sown wheat and non-irrigated white clover. This corresponds to a reduced rotation length from three to two years. Simultaneously, the greenfeed oats catch crop area is reduced from 85 hectares to 15. These changes allow a reduction of fuel use below base model use of 17 percent, and a reduction of total energy use by 12 percent.

Up to and including a 900 percent short run price increase, the farm system is the same as that given at the 600 percent level. However at the 900 percent level, the effect of resultant increases in the prices of non-fuel inputs (in the longer run) is to additionally reduce the land area under tick beans by five hectares transferring this to white clover production. Fuel use is thus reduced by a further 1.4 percent.

In response to a 1000 percent increase in the price of fuels only, tickbeans pass out of the solution entirely, the land being used for white clover production. At this level of price increase the farm is half given over to conventionally cultivated autumn sown wheat rotated with the remaining half occupied by the break crops of mostly white clover with about 14 hectares of freezing peas. This basic two year rotation also includes the utilisation of all winter fallow available with greenfeed oats.

5.2.2 Changes in Input Use. Similar shifts are encountered in the pattern of input use to those occurring in the early stages of the rationing scenario. High fuel prices encourage reduced fuel use. The resultant changes in the farming system adopted in order to gain fuel savings are also associated with higher input levels of sprays and combine harvester hours. Changes are also associated with lower inputs of nitrogenous fertilizer and tractor hours (and therefore implements). The net effect is a reduction of total energy used by the farm. Input use changes are shown graphically in Figures 5 and 6.

Inferred in these results is confirmation of the findings of other authors that indicate only a small response of farm fuel demand to higher fuel prices (i.e. the price elasticity of demand is in fact very low). The reasons behind such inelasticity are complex, (van Arsdall, op. cit.), but a major factor in this case must be that, although changing relative input prices occur and provide incentive to substitute between inputs, changes are constrained by the efficiency (both economic and energetic) of the alternative systems which could actually be adopted. With no close alternatives to fuel inputs, substitution will only become useful and profitable to adopt under extreme conditions (such as very

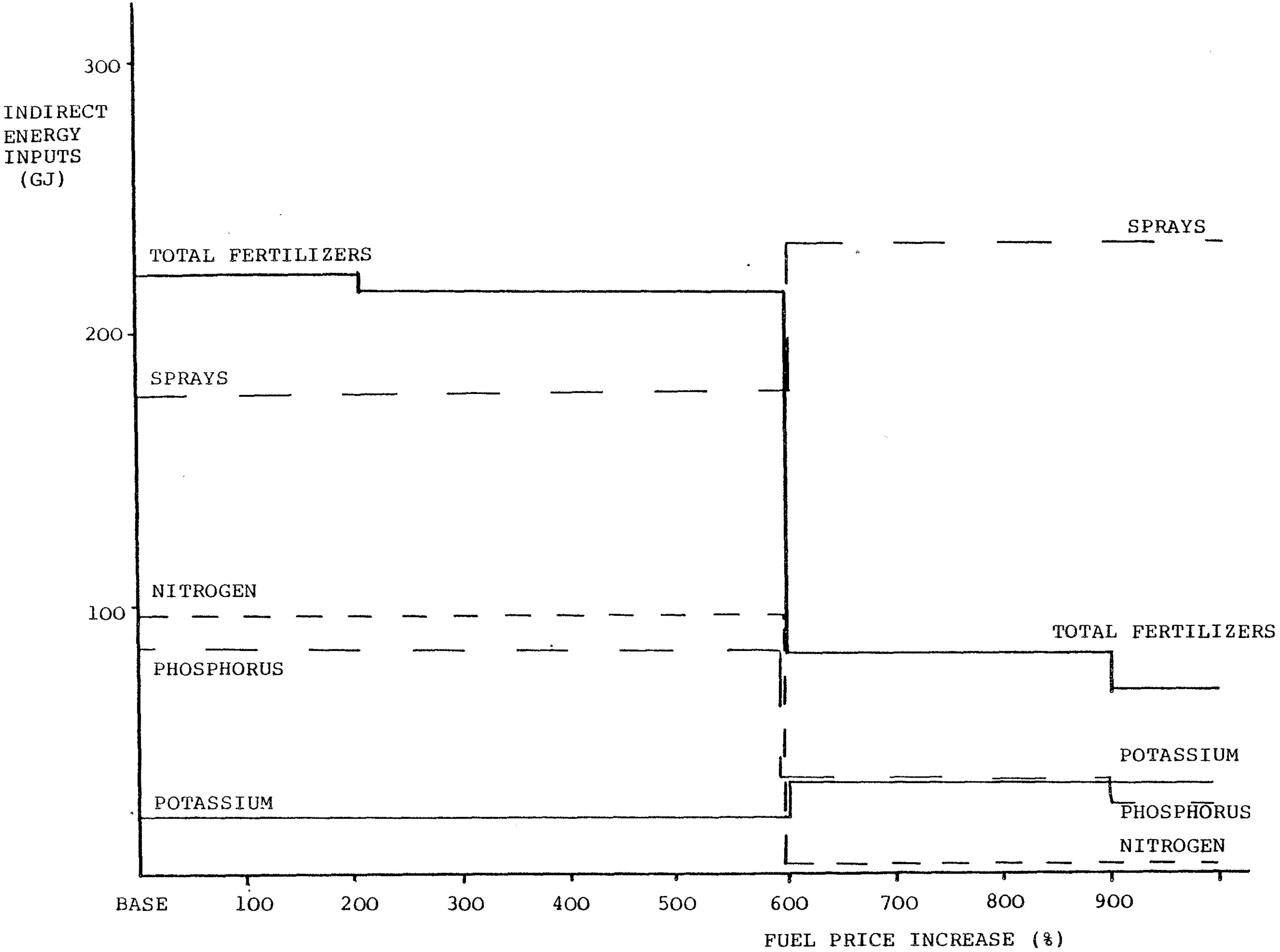

Figure 5 : Fuel Price Increases; the Long Run Effects on the Farm Use of Inputs (Chemicals).

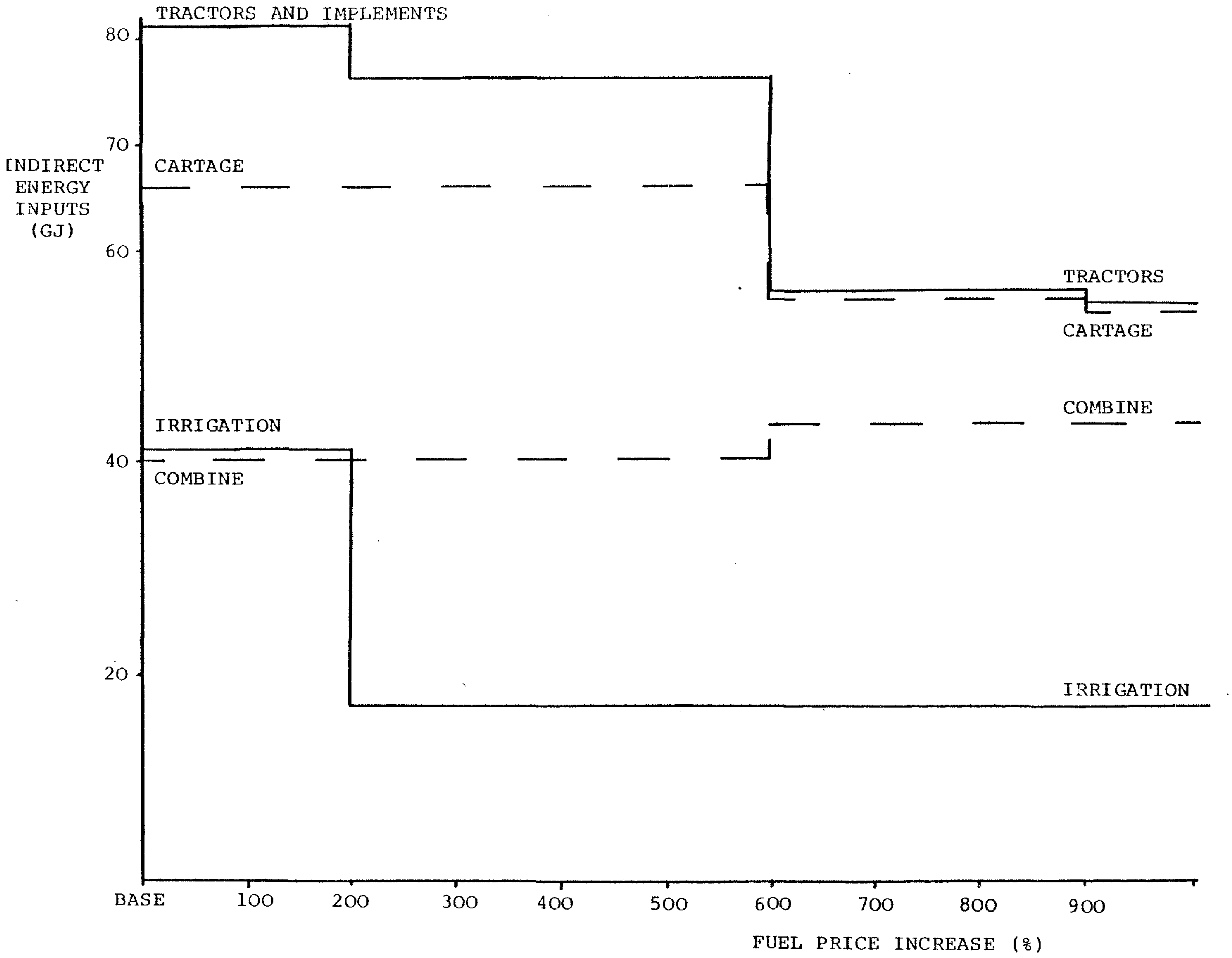

Figure 6 : Fuel Price Increases: the Long Run Effects on the Farm Use of Inputs (Machinery).

high fuel prices), and even so, only small energy savings may therefore be possible.

5.3 The Effects on Farm Profitability of Fuel Rationing and High Energy Prices

Table 5.3 and Figure 7 show the levels of total costs and revenues which result from the farm systems adopted during fuel rationing that are shown in Table 5.1 above. Initial fuel savings induce farm system changes that decrease then actually increase the value of crop output, but simultaneously the value of grazing revenues declines. After reaching a peak at the 20 percent level, gross cropping revenue steadily diminishes whilst grazing revenue declines throughout all levels of rationing tested, except for a plateau between the 30 and 40 percent levels.

Total revenue declines initially but plateaus between the 5 and 20 percent levels. Up to the 20 percent level, fuel savings are made that reduce fuel costs by \$390 through adopting a system of production which generates \$2960 less total output value.

Total costs fluctuate throughout neither showing consistent increase nor decrease. It is likely that, if the complement of mobile machinery owned by the farm were allowed to change during the analysis (rather than being held at base model level) then the farm would sell

TABLE 5.3

The Effects of Rationing on Farm Revenues and Costs

REDUCTION IN FUEL USE		BASE	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
GROSS CROPPING REVENUE	$	115130	113294	115340	117398	117559	114608	111366	108450	105534	102291	94927
GRAZING REVENUE	$	9980	8761	6755	4748	3771	3259	3347	3347	3347	3329	3088
TOTAL REVENUE	$	125110	122055	122095	122146	121330	117867	114713	111797	108881	105620	98015
TOTAL COSTS	$	48012	45503	46290	47088	47400	46220	45966	46290	46615	46639	42981
NET FARM REVENUE	$	77098	76552	75805	75058	73930	71647	68747	65507	62266	58981	55034

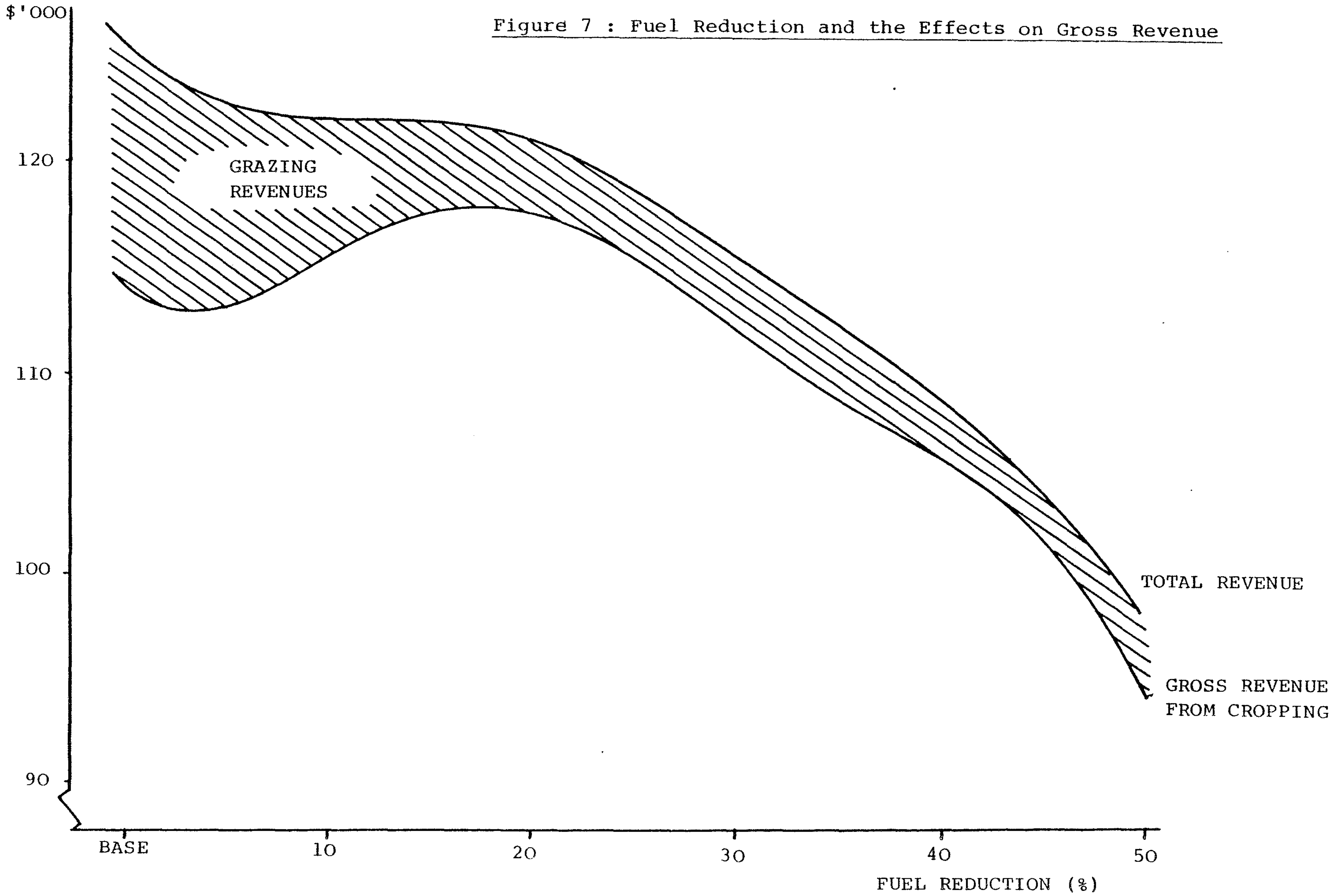

Figure 7 : Fuel Reduction and the Effects on Gross Revenue

excess machinery as it became surplus to requirements, and the saving of semi-fixed costs could slightly reduce total farm costs. Net revenue, as the combination of total revenue less semi-fixed and variable costs, declines throughout.

Table 5.4 shows similar information for the short and longer term effects of price increases for petroleum.

Similar effects occur on gross cropping revenue as occurred during the early stages of rationing. After an initial drop, crop revenue rises to a maximum at 600 to 900 percent price increases (or around a 17 to 20 percent fuel reduction). Although grazing revenues decline throughout, the simultaneous increase occurring in cropping revenue acts to stabilise total revenue for all price tested increases of 200 percent and above.

As expected, a significant difference appears in farm costs between the rationing and input price rise scenarios. Although in the short run only fuel prices increase, and fuel use consequently tends to decline, the price effect outweighs the reduction in use and total costs consistently increase. In the long run as non-fuel inputs are allowed to increase in price, costs increase at a faster rate still. Given this, net revenues under short run price increases are reduced below those under rationing, and in the long run are reduced below

TABLE 5.4

The Short and Longer Run Effects of Fuel Price Increases on Farm Revenues and Costs

INCREASE IN FUEL PRICE (%)													
SHORT RUN		BASE	100	200	300	400	500	600	700	800	900	-	1000
LONG RUN		"	100	200	300	400	500	600	700	800	-	900	-
GROSS CROPPING REVENUE	$	115130	115130	112063	112063	112063	112063	118325	118325	118325	118325	118325	117520
GRAZING REVENUE	$	9980	9980	9968	9968	9968	9968	3841	3841	3841	3841	2835	4082
TOTAL REVENUE	$	125110	125110	122031	122031	122031	122031	122166	122166	122166	122166	121160	121602
TOTAL COSTS SHORT RUN	$	48012	50757	50417	53111	55805	58499	61085	63358	65631	67904	-	69613
LONG RUN	$	48012	52602	54101	58637	63173	67704	72120	76233	80345	-	83410	-
NET FARM REVENUE SHORT RUN	$	77098	74353	71614	68920	66226	63532	61081	58808	56535	54262	-	51989
LONG RUN	$	77098	72508	67930	63394	58858	54322	50046	45933	41821	-	37750	-

those in the short run. Table 5.5 and Figure 8 compare farm net revenues under each scenario for common levels of fuel use. Four fuel reductions have been found by increasing energy prices and these levels of fuel use are used to act as bounds on fuel availability in much the same way that rationing is imposed. The systems were found to be identical for each level of fuel use. The various levels of farm net revenues are shown below.

TABLE 5.5

The Relative Effects of Pricing and Rationing Scenarios on Farm Net Revenues

Target Fuel Reduction	Rationing	Short Run Pricing	Long Run Pricing	Equivalent Price Increase
% of Base	$	$	$	%
Base	77,098	77,098	77,098	0
1.9	77,082	71,614	67,930	200
17.3	74,866	61,081	50,046	600
18.7	74,490	-	37,750	900
19.5	74,276	51,989	-	1000

The comparison demonstrates that if a free market pricing policy (or a policy to increase prices artificially by tax increase) is adopted to reduce fuel consumption, then a fuel price increase of 200 percent will achieve the same quantity reduction as a 2.0 percent rationing policy but

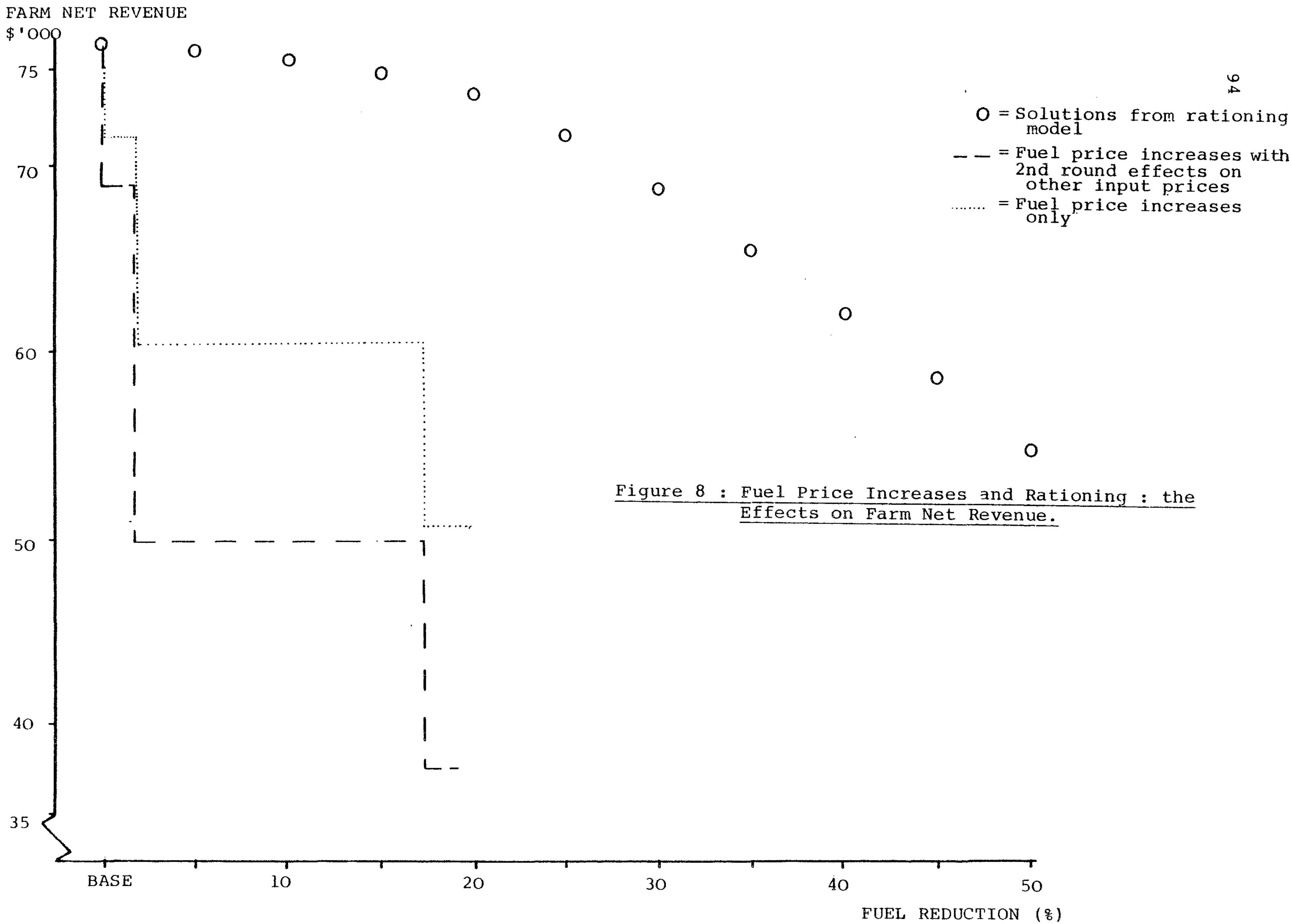

Figure 8 : Fuel Price Increases and Rationing : the Effects on Farm Net Revenue.

will involve, especially in the longer run, much reduced farm incomes. Net revenues under rationing are far less sensitive to fuel use than those under free pricing.

5.4 The Effects on Energy Efficiency of Fuel Rationing and High Energy Prices

National energy policies are aimed at improving the efficiency (both economic and energetic) with which energy is used. Such policies work by changing either the effective price or quantity available of scarcer and more costly energy types such as oil, causing through input substitution, change in the balance of direct and indirect energy inputs. Direct energy is saved but leads to increased reliance on indirect energy inputs. Figure 9 shows the proportionately increasing amounts of indirect energy required to save successive five per cent steps in fuel use, explaining the non-linear nature of the total energy requirement curve. For rationing above 25 percent, the indirect energy requirement which increases relative to the direct energy input throughout, begins also to increase absolutely. In terms of total energy requirement, the efficiency of fuel reduction policies is seen to diminish with the continued reduction of fuel use.

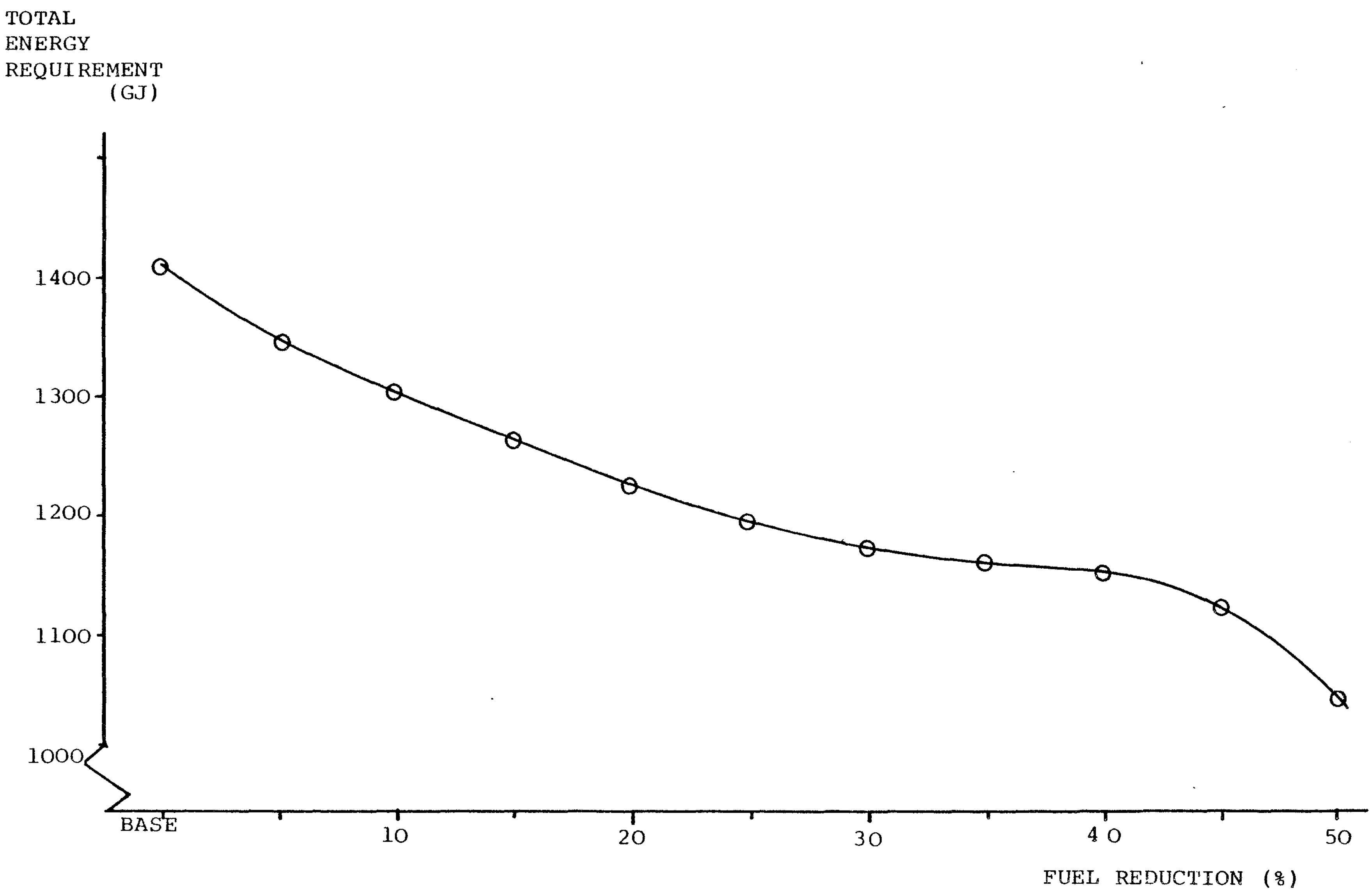

Figure 9 : The Effect of Reduced Fuel Use on the Total Farm Energy Requirement

The technical efficiency with which energy inputs are used to produce agricultural output can be viewed as energy input per unit of output. Government policy may currently be aimed at reducing imports of fuel energies and efficiency would thus be measured as fuel energy input per unit output; because of the issues of substitution it would also be useful to determine the overall energy efficiency of the farm measured as total energy input per unit of output. Table 5.6 shows these measures of efficiency with reduced fuel use. Units of output used for this comparison are "dollars value of gross output", which, because output prices are constant, is a reasonable measure to adopt.

Policies which lead to high energy prices and fuel rationing can increase technical efficiency on the model farm. Whilst fuel use efficiency increases throughout all levels of each scenario, total energy efficiency does not, except under raised energy prices. Under fuel rationing the efficiency of total energy use rises to peak at the 20 percent level of rationing. At levels above 20 percent for rationing, total energy use becomes less efficient. Fuel efficiency and total energy efficiency are thus definitely not synonymous.

TABLE 5.6

The Effect of Fuel Price Increases and Rationing on Energy Efficiency

Rationing Model		Base	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Fuel Energy Input	GJ	554.98	527.06	499.35	471.64	443.96	416.17	388.25	360.22	332.17	304.18	276.41
Total Energy Input	GJ	1506	1440	1391	1342	1301	1267	1246	1229	1213	1190	1105
Gross Dollar Output	$	125110	122055	122095	122046	121330	117867	114713	111797	108881	105620	98015
Fuel Energy per Dollar Output	MJ/$	4.44	4.32	4.09	3.86	3.66	3.53	3.38	3.22	3.05	2.88	2.82
Total Energy per Dollar Output	MJ/$	12.04	11.80	11 39	11.0	10.72	10.75	10.86	10.99	11.14	11.27	11.27

Pricing Model					
	Long Run	200	600	900	-
	Short Run	200	600	-	1000
Fuel Energy Input	GJ	543.73	459.11	451.19	446.89
Total Energy Input	GJ	1470	1320	1310	1305
Gross Dollar Output	$	122031	122166	121160	121602
Fuel Energy per Dollar Output	MJ/$	4.46	3.73	3.72	3.675
Total Energy per Dollar Output	MJ/$	12.05	10.80	10.81	10.73

5.5 The Effects of Changing Output Prices on Model Results

So far, the analyses have examined the farm system either under changing input prices or reduced fuel usage, all other factors remaining constant. Changes in the production system have invariably led to falling net farm revenues with the assumption that market prices remain constant.

In an earlier section it has been assumed that the increase in fuel prices leads to an increase in the prices of products from other industries, but not agriculture (see Section 5.2). The reaction in world food markets to fuel supply shifts may lead to an increase in the prices of agricultural products if food output declines. This would increase farm gross revenues and could, if large enough, completely offset the energy cost increases. In Table 5.7 the simultaneous increases in all output prices necessary to maintain farm total revenues are shown for the scenarios.

Farm net revenues are highly responsive to output prices and the long run effects of a doubling of fuel prices would be offset by a 3.7 percent commodity price rise. Higher costs under fuel price increase scenarios, as expected, require greater increases in prices received to offset fallen net revenue.

TABLE 5.7

Farm Output Price Increases to Offset Falling Revenues

Rationing Model											
Fuel Reduction	Base	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%
Compensating Price Increase (%)	0.0	0.4	1.1	1.7	2.6	4.6	7.3	10.4	13.6	17.2	22.5
Short Run Price Model											
Fuel Price Increase	Base	100%	200%	300%	400%	500%	600%	700%	800%	900%	1000%
Fuel Reduction	0%	0%	2%	2%	2%	2%	17%	17%	17%	17%	19.5%
Compensating Price Increase (%)	0.0	2.1	4.5	6.7	8.9	11.1	13.1	15.0	16.9	18.7	20.6
Long Run Price Model											
Fuel Price Increase	Base	100%	200%	300%	400%	500%	600%	700%	800%	900%	
Fuel Reduction	0%	0%	2%	2%	2%	2%	17%	17%	17%	19%	
Compensating Price Increase (%)	0.0	3.7	7.5	11.2	14.9	18.7	22.1	23.4	28.9	32.5	

In practice farm output prices are highly variable in real terms and seldom move simultaneously, or even in the same direction as a consequence of a stimulus (in this case, rising energy prices). Although commodity prices in general may increase as rising fuel costs shift market supply curves to the left, there is more likely to be a different movement in prices of products relative to each other. This would modify the pattern of change shown in the model results so far, which assumed as constant prices and relative prices. However, to predict the relative magnitude and direction of change likely in relative product prices is a very precarious exercise, which is not embarked upon here, but the effects of change in product prices can be seen in reduced cost data from the model output. Reduced costs are equivalent to the improvement in revenue of an activity (all other revenues remaining constant) necessary to bring that activity near the optimal farm plan, near enough to become a marginal proposition. Table 5.8 shows the improvements necessary for the optimal farm under 1978 conditions (i.e. no fuel price increases, or rationing applies).

Since revenue is the product of output price and yield, the revenue increases could be considered as the result of change in either price, yield or both together. The activities more sensitive to changed revenue are the same crops as those currently grown, but which do not feature in the optimal base model. Minimal cultivation,

TABLE 5.8

Relevant Reduced Cost Data (generated from the base solution and the 5 per cent rationing solution).

ACTIVITY	REDUCED COST	REVENUE[A] PER HA	INCREASE IN REVENUE TO MAKE EACH ACTIVITY MARGINAL	
	$[B]	$	%[B]	%[C]
Giant Rape	0	47	0	8
White Clover (non-irrigated)	- 1.9	550	0.3	0
Tick Bean, spring sown	-12.8	704	2	5
Barley (ex break crop)	-10.1	507	2	10
Autumn wheat (ex cereal)	-28.7	516	5	3
Tama ryegrass	-48.2	586	8	19
Spring wheat (ex break crop)	-59.6	480	12	18
Manawa	-85.8	491	17	22
Irrigated spring wheat (ex break crop)	-98.0	504	19	27
Spring wheat (ex cereal)	-91.0	420	22	14
Autumn wheat, minimal cultivation (ex break crop)	-106.3	444	24	18
Autumn wheat, minimal cultivation (ex cereal)	-117.8	432	27	16
Freezing peas	236.0[D]	844	28	19
Tama seed	-124.9	438	29	42
Irrigated spring wheat (ex cereal)	-140.2	444	31	31
Sheep (fattening hoggets)	-145.4	436	33	35
Spring wheat, minimal cultivation (ex break crop	-153.4	384	40	38
Fodder beet	-130.8	309	42	44
Irrigated spring wheat, minimal cultivation (ex break crop)	-173.8	408	43	42
Irrigated spring wheat, minimal cultivation (ex cereal)	-182.3	396	46	39
Spring wheat, minimal cultivation (ex cereal)	-187.9	336	55	45
Seed peas	-191.7	317	60	170
Kale	-226.0	205	110	115
Lucerne for hay	-257.2	148	174	158
Lucerne for grazing only	-299.7	125	241	213
Pasture for hay	-295.9	94	314	280
Pasture, grazing only	-321.4	84.5	380	335

[A] Including value of feed, sold ex-farm.

[B] From the 1978 base model solution

[C] From the 5% rationing model solution

[D] Freezing peas would be grown on a greater area, but have been limited to 17.6 hectares by contract. The per hectare revenue would have to fall by $236 before less than 17.6 hectares would be optimal.

which would be a 'new' technology on this farm is relatively insensitive, requiring yield improvement of about 28 per cent before becoming even a marginal proposition. (A wheat price improvement would not improve the attraction of minimal cultivation relative to conventional cultivation, thus any revenue improvement must come from reduced suppression of yield).

Cropping alternatives are poised more closely to the optimal solution than pasture and stock-related enterprises, there being needed very large increases in stock prices, feed prices or yields of grazed pasture grass and lucerne for these enterprises to dislodge the traditional cropping activities.

The effect on the sensitivity of enterprises during fuel rationing is also illustrated. Where the proportionate change in unit revenue has become larger, that activity is becoming less attractive since it requires a greater rate of return for the activity to be a marginal proposition. Generally, wheat crops except those that are irrigated become more attractive in times of reduced fuel and break crops, along with sheep fattening, becomes less attractive. However, minimal cultivation, pasture for grazing and for haymaking become more attractive under reduced fuel use.

5.6 Change in the Marginal Productivity of Resources

The economic optimum is attained where the return to the most limiting resource is maximised. Where fuel use is successively reduced there is a change in the resource that is most limiting: only at high levels of rationing is fuel the most limiting resource. Resources that are not limited in supply to the farm are used to the point where the extra value of production gained by the use of the last unit of resource is equal to the market price (per unit) of the resource. However, when a resource becomes limited in supply the money value of the marginal product is greater than the price of the resource. This value is the shadow price of the resource, and Table 5.9 shows shadow prices for fuel, and other inputs to this farm system.

TABLE 5.9

Shadow Prices of Resources ($ per litre)

Fuel Rationing Level	10%	20%	30%	50%
Diesel	1.17	2.48	4.48	5.41
Petrol	1.20	2.51	4.51	5.45
All fuels	0.99	2.30	4.30	5.23
Land Use in Period 4 ($/ha)	18.9			
Land Use in Period 6 ($/ha)	231	139	30	

These results illustrate the productivity of fuel used on this farm, since if a ten per cent fuel cut was imposed, the last litre denied to the farm (which would have cost the farm somewhere in the region of 18 to 20 cents) causes change in the farm which, at the very least, causes a loss of 99 cents in net revenue to the farm. The greater the cut in fuel use, the greater the marginal loss of farm net revenue to the last litre of fuel taken away.

As fuel use is restricted and the shadow price of fuel increases there is a decrease in the shadow price of the limiting land supply (i.e. that available in periods 4 and 6). The reduction in fuel supply causes a reduction in the productivity of the marginal unit of land, until at about a 45 per cent fuel use cut, land begins to pass out of production, implying a zero shadow price at this point.

This is an interesting result because whilst it is intuitive that agriculture will have to deploy more land to meet food demand during an energy supply crisis, it implies that the farm manager is motivated in a way which tends towards leaving some of his land unused. The difference is interpreted as the result of divergent objectives : on the one hand the world agricultural objective is assumed to be maintenance, or increase in, current world food supply levels, whereas the producer's objective assumed here is net revenue maximisation. It is possible that it will, at some stage, be in the producer's interest to leave land idle rather than to produce food on it.

5.7 Comments on Model Results

The accuracy of the results has been qualified by the validation procedures of Chapter 4. However, before drawing conclusions from these results, certain points should be borne in mind.

The first cautionary point is that in the preceding analyses only convenient discrete points have been chosen for examination. Between these discrete intervals there may occur changes in the solutions which have not been included. Interpolation between the observations will not be adequate to estimate with accuracy mid-point solutions.

The model is not stochastic and therefore no account has been made for uncertainty in the analyses. Uncertainty of environment exists in technology changes, variations of prices (of inputs, output and both relative to other prices) and fluctuations in yields. Relative price movements, yield and technology-induced variations would change the values of coefficients in the model and have not been examined: for the purposes of this study, these have been assumed as constant, being embodied in all model coefficients which are specified under average conditions.

It is intended that the model be of easily manageable size; extensions to examine particular areas of the model in detail are quite feasible. It is quite possible that with more detail included the farm system reactions may be modified and smoothed. For example, the inclusion of reduced tillage options between conventional and minimal tillage practices may prove useful as an interim substitution possibility between the two. The data requirements of such additions may involve extensive research effort to determine the trade-offs between yield and cost reduction, information which is currently unavailable.

Lastly, in applying these results to the particular farm, or indeed to any specific farm, the rates at which the farm systems change under either scenario are likely to vary widely from farm to farm. The farm uses of fuel are not restricted in practice to those included in the model; fuel used 'non-productively' (drain cleaning etc.), and for non-business purposes acts as a buffer to change. If savings in fuel use can be made in these buffer areas, the production systems on such farms may not have to be adjusted in the short run. The importance of the quantity of non-productive fuel consumption is stressed: on the mixed cropping farm, unaccounted fuel use, contracting out and non-productive uses accounted for over ten per cent of farm diesel use. The margin may well be larger for petrol consumption.

CHAPTER 6

SUMMARY AND CONCLUSIONS

A linear programming model is developed, validated and used experimentally to investigate the likely effects of fuel rationing and high fuel prices on an intensive mixed cropping farm in Canterbury. The model assumes that the farm will operate throughout scenarios tested in such a way as to maximise the total net revenue (being gross revenue less variable and semi-fixed costs) resulting from the production of typical farm crops and stock output. The short run is that time period in which farm plans can change fairly dramatically, i.e. one or two seasons ahead. The longer run refers to an environment where technology, output and input prices are changed. This model is used, therefore, to investigate possibilities for the short run future. Discussion of the long term is limited to speculation.

6.1 Summary of results

The impacts of a policy to restrict fuel use on farms by rationing, cause the system of farming to change significantly from the systems that are viable currently. Fuel use must be successively cut at the margin, and this effectively reduces the possible annual work output of machinery kept at the farm.[28] To make the most profitable use of a limited fuel

[28] Since machinery and labour are to a degree mutually determined, the physical work output of labour will also be reduced. This may lead to a reduced demand for labour as machinery use is cut.

supply, the first activities to be reduced and shed are those with the lowest overall marginal value product to fuel. Table 6.1 summarises the order in which activities are rationally removed and the activities which are introduced to replace them.

TABLE 6.1

Activity Changes in Response to Reduced Fuel Use

Outgoing Activity	Replacement Activity
Contracting out of surplus machinery capacity	-
Angletow irrigation of white clover	Non-irrigated white clover
Second cereal crop of spring barley	White clover and first winter wheat
Tick beans, autumn sown	White clover and first winter wheat
Greenfeed oats winter catch crop	Winter fallow (before freezing peas)
Freezing peas	White clover
First winter wheat, conventionally cultivated	Reduced cultivation first winter wheat
Reduced cultivation first winter wheat)	Land becomes idle
White clover)	

These changes lead to longer utilisation of land by crops (there being less fallow) and shorter rotations (two year instead of three year cycles).

The changes in the productive mix of activities on the farm are associated with changes in the mix of inputs.

Inputs of fuel (bearing directly on maximum input of machinery) are initially reduced, but other inputs actually increase in their importance in the mix under the scenarios tested. The use of all fertilizers expressed as a group tends to decline led by a sharp drop in nitrogen usage, but potash use increases slightly. Cartage requirements are reduced because the volume of input and output flows becomes contracted. The viability of irrigation diminishes. On the other hand the use of sprays increases consistently so that although generally there is a movement to lower total energy, that is not true for all inputs. Total costs tend to decrease at a slow rate as fuel use is restricted.

Total energy efficiency of the whole farm (measured as total energy input per unit of total gross revenue) improves to a maximum at a 20 per cent fuel reduction, thereafter declining. Policies to reduce agricultural <u>fuel</u> consumption are therefore not automatically associated with increased total <u>energy</u> efficiency and whilst fuel imports may be reduced, other indirect inputs of energy may increase in volume imported.

Gross farm revenue tends to decline with lower fuel use, at a relatively slow rate up to a 20 per cent reduction and more rapidly thereafter. Stock activities assume a lesser importance as in aggregate, grazing revenues fall relative to gross cropping revenues.

Results from the energy price increase scenarios show markedly similar trends (in farm production system input use and output volumes) to those under a rationing policy. The analysis shows quite discrete 'jumps' in production parameters at 200, 600, 900 and 1000 percent energy price increases (the resulting fuel savings being of 2.0, 17.3, 18.7 and 19.5 percent respectively). The magnitude of price increases relative to the resultant saving in fuel use indicates an initially low and slightly increasing price elasticity of demand for fuel.

When expressed in terms of the order in which activities decline within the farm system, comparison between pricing policies and rationing shows clear similarity. Initially irrigated clover, then second spring barley, tickbeans and greenfeed oats decline in area under both scenarios and are replaced by the same incoming activities (see Table 6.1).

Changes in input use, output produced and gross revenue also follow the same patterns (the system changing in similar ways). Input prices do however change, and there are substantial and continuous increases in total costs (despite there being no change in farm systems at several levels). In the longer run, increases in the price of other inputs further increase total costs: farm net revenues are greatly lowered when the indirect effects (through non-fuel input prices) are included. The basic similarity between optimal systems under comparable fuel input levels suggests that likely emergent farm systems depend on the level of fuel used, not on how that usage is restricted.

However, the levels of farm net revenue do depend on how fuel use is restricted. Gross cropping revenue increases initially in absolute terms and relative to grazing revenue (which declines absolutely) with fuel rationing. After about a 20 per cent reduction in fuel use, cropping revenue turns down. Thus within a general trend for total farm output to decline, there is a tendency for livestock grazing to decline in importance relative to cropping. A low energy sheep system *per se* will not become a rational choice unless the marginal value of fuel used in sheep production can be increased. It is envisaged that sheep systems will become less rather than more important under such circumstances.

Falling output levels and rising energy costs act to reduce seriously farm net revenues. A 200 per cent energy price increase will decrease net revenue by $9168 from $77098 in the longer run. Whilst system changes are capable of increasing the physical efficiency with which many inputs are used, they cannot be changed sufficiently to offset the substantial loss of farm income. Even though resource use is cut by six per cent, resource costs increase by $7089; had no change in the farm system occurred and resource use did not alter, resource costs would have been higher still by $2102.

At the same time as resource costs increase, the value of farm output decreases by $3079. So, despite a six per cent resource saving as the farm system adjusts to maintain the optimal net revenue level, the net loss to the agricultural sector is $10,168 if fuel prices treble. If the sector imported all of the resources needed and exports all of its output, then this will represent the order of magnitude of the maximum net loss to the balance of payments of just one farm.

Given that these effects are likely to occur when oil prices escalate, policy makers need to know whether Government intervention into the allocation of fuel is likely to reduce those detrimental effects on the economy.

6.2 Conclusions

Escalation of world fuel prices expected in the period 1985-95 will cause change in the economic environment within which current farming systems operate. Using a static linear programming model to show the effects of a trebling of fuel prices in the 1978-79 farm system, net farm revenue decreased by 12 per cent (taking account of the rising costs of other inputs as a consequence of rising fuel prices). It is, therefore, likely that fuel price escalation would lead via increased farm costs to significant reductions in the profitability of mixed cropping farms, although the organisation of production on the optimal farm would change only under very large fuel price increases. A critical assumption used here is that of constant output prices.

6.2.1 Implications of Rising Fuel Prices

This study concludes that the optimal farm system, the level and mix of outputs is insensitive in the short run to fuel price increases. A simulated trebling of the 1978 price (17.6 cents per litre) results in a 2 per cent cut in fuel used for productive purposes. The farm's demand for fuel is very price inelastic.

Additionally, farm incomes are found to be quite sensitive to rising energy prices (falling 12 per cent, in the above case). While the farm has few sufficiently "close" (i.e. profitable) alternative uses of fuel, it is rational to meet the increased fuel costs of sustained levels of fuel consumption, albeit at the loss of profits, rather than to switch systems to a lower level of fuel consumption. The high marginal value of fuel used on the farm means that the farm will, in a free market, be prepared radically to bid up fuel prices. Examination of the marginal value of fuel used in other sectors of the economy is necessary to determine which sectors would be able to compete with agriculture, but it seems likely that farms would be in a strong position in competition for a declining fuel market.

Whilst the farm may be able to survive the income effects of a doubled fuel price in the short run, perhaps through curtailed investment, such a situation may, if continued, have a depressing effect on farm performance that this model cannot show. Reduced investment, if continued into the longer run, will ultimately affect output as machinery and plant become excessively aged.

6.2.2. The Implications of Rationing

In response to a stimulus of rationed fuel supply, the optimal farm system is found to be quite sensitive. While this leads to a change in output mix, the value of output is less sensitive, and incomes decline marginally. This result assumes that the cost of energy does not increase and thus the dramatic income effect under increased energy prices is avoided.

On this farm, during progressively increased fuel rationing, a permanent sheep flock remains marginal, and the general shift towards cereals leaves less feed to support agisted stock activities.

Results show the rational decision is to maintain the return to the most limiting resource. However, fuel itself does not become the most limiting factor until it displaces land, at a rationing level of 45 - 50 per cent.

Fuel rationing can work to save fuel on farms, therefore, without a serious effect on the income of the farmer. The farm system is sensitive to fuel use but insensitive to fuel prices. Change is rapidly stimulated via direct manipulation of fuel supply, and more so than under a pricing scenario. Thus it seems that if fuel reductions on this farm are required as a matter of policy, rationing would more directly achieve this than pricing with less effect on incomes. For any given target level of fuel use stimulated, rationing and price increases produce identical optimal systems although cost increases under pricing provide a lower income to the farm.

This analysis is perhaps rather pessimistic in the outcome for farm incomes since output prices have been assumed constant and two income effects have actually been implicitly held constant by this assumption. First is the absolute level of output prices, and thus the pessimistic effects shown for farm incomes could be reversed by relatively small gains in product prices.

Second, the level of relative product prices is important. The statement of the farm's price inelasticity of demand assumes that all other things remain equal. Relative output prices almost certainly will not remain constant, judging by past experience, so results will lay inaccurate emphasis on the system changes likely. Results are, therefore, indicative of change caused by inter-enterprise differences in relative energy (fuel and indirect energy) costs, without the potentially more influential effect caused by relative price movements.

6.2.3 Policy Implications

Realising the limitations of the static linear programming formulation (the constant output price and technology assumptions included, the inherent weakness of a single case study to determine the national effects) there are some major conclusions arising which have relevance for policy.

First, farm output (measured as gross revenue, see p.89) is positively related to farm fuel use in the short run, even taking account of some technological alternatives to conventional production systems (e.g. minimal cultivation). A policy to reduce farm fuel use will have the effect of reducing farm output in the short term.

The second point follows on from the first, arising from the fact that farm revenues are the product of output prices and farm output levels. Therefore, a policy involving reduction of farm fuel use will also have the effect of reducing farm revenues and incomes, output prices and technology remaining constant. The effect of reducing the amount of fuel used on this farm by one litre (costed at 17.6 cents) is a reduction of farm income (revenue minus semi-fixed and variable costs) of 99 cents.

Third, the level of farm income is more sensitive to product prices than to energy prices. Small gains in product prices received for New Zealand produce can offset larger percentage increases in energy prices. This would appear to justify a continued national effort to press for higher export prices in foreign markets, and to seek out the markets that will return the higher prices.

Fourth, as fuel use is reduced there is a countering growth of indirect energy inputs such as sprays and some fertilisers. Though complex, the net effect is that other energy is increasingly used as fuel use decreases. Thus care must be exercised in calculating the full consequence of fuel import saving to account for the extra inputs, perhaps imported, which are required to compensate.

At certain stages (see p.98), it seems that a fuel reduction policy may not achieve energy reduction but may merely shift the dependence from imported fuels, to imported agricultural inputs.

It is apparent that a policy to reduce fuel use in agriculture by rationing, or by increasing the price farmers pay for fuel cannot be consistent, in the short term, with policies to increase agricultural output. Unless significant and continuing increases in product prices are expected a fuel reduction policy also conflicts with objectives of maintenance of farm incomes and agricultural export performance. A clear statement of government objectives needs to be made that carefully avoids the confusion which could arise. Policy-makers must make clear the long-term objectives for agriculture that take into account the likely changes in energy markets and the role that this sector is expected to play in a future economy. This is a critical step, since all policies can then be evaluated in terms of an overall strategy, and conflicts should not arise. In this case the choice of 'best' policy examined cannot be determined until these objectives are known, and certainly this study can shed little light on the longer term effects of rationing and energy price increases.

However, in the short term the government may be forced into a position where it might decide to intervene in the allocation of petroleum fuels within the country as a short term measure to overcome supply irregularities. Before it decides whether fuel rationing by price or by quota in agriculture would be beneficial to the national interest, the government may have to decide whether <u>any</u> reduction of fuel in agriculture is sensible. With the economy dependent on agricultural output for export, reduction of fuel use would reduce output. Over a season agricultural incomes and output may suffer by such changes but a vital period of only two months without access to any fuel (say at harvest) could have disastrous consequences which it is in the national interest to avoid. Furthermore, the marginal litre of fuel used on this farm costs the farmer 17.6 cents but generates 99 cents worth of farm income in the major export industry. Other industries should also be screened to determine their return to fuel relative to that of fuel used in agriculture. As fuel becomes the most limiting factor, in a short term crisis allocation must proceed on the basis of preferential use in those industries with the greatest return to fuel, and agriculture would probably be rated highly on such a scale. For these reasons, it may be best to protect agriculture as much as possible in the event of a short run fuel supply breakdown and guarantee the industry its fuel requirements. Fuel savings would be made in other areas.

Forced to decide between shorter term policies of rationing by quota or price, government would have to look to their policy objectives. Farm incomes would suffer under price increases, and because of price resistance market competition would not induce this farm to cut back its fuel use until very large (treble) price increases occur. In this case the farm manager should elect to forgo some profit to maintain the supply of fuel. Output (gross revenue) is insensitive to fuel price, and if other farms respond showing similar characteristics, then agricultural exports would not be adversely affected.

Under rationing, farm incomes are only slightly reduced, but because output is more sensitive, export revenues may be at risk of reduction. Other resources (such as pesticides) would be increasingly used and there may be changes in the mix of output, which in turn would alter the value of output. The choice between these as policies for the shorter term will depend on the government's objectives. In the final analysis it must come down to whether it is more in the national interest to jeopardise short-term export earnings or farm incomes, and which is of greater priority in the longer term development of New Zealand agriculture.

In the longer-term view, policy-makers have to face a choice between certain objectives for agriculture. The choice is between a supported agriculture characterised by guaranteed incomes and stability with significant intervention by government, and an independent agriculture adjusting when change is demanded by market circumstances perhaps characterised by instability and fluctuating incomes. Although the market philosophy will lead to difficulties for producers, a free market approach may be the best way to maintain New Zealand's competitive advantage in agriculture that has allowed exports to compete in overseas markets. This advantage is critical to the country's economy now and is likely to be even more so in future.

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APPENDICES

APPENDIX I

Machinery Costs

Table I.1

Total Energy Requirements and Dollar Costs of Farm Machinery

ITEM	HEADER CLAAS DOMINATOR		TRACTOR-62 H.P. MASSEY FERGUSON 165		IMPLEMENTS[i]		TRUCK BEDFORD (7 ton)	
LIFE[a]	20 yrs & 120 hrs pa		15 yrs & 400 hrs pa		13.64 yrs & 13650 hrs		20 yrs & 5000 km/yr	
WEIGHT kg[b]	6390		2403				5500	
ENERGY SEQUESTERED (GJ T.E.S.)[c]	594.27 (weight x 93MJ)		223.479		505.27		511.5	
COST, INITIAL, 1975 (Ledger Entry)	11 400		4 972		6250		4 400	
FIXED COSTS:	$	GJ	$	GJ	$	GJ	$	GJ
DEPRECIATION @ 50% Cost[d]	285.00	14.86	165.73	7.449	229.11	18.53		
INTEREST @ 12% pa (on 1975 $ cost)	1 368.00		596.64		750.00		528.00	
INSURANCE	46.75		14.28		23.52		24.00	
REGISTRATION	18.90		18.90				209.87	
TOTAL	1 718.65	14.86	795.55	7.449	1002.63	18.53	761.87 or 15.2 c/km	
VARIABLE COSTS:	$	GJ	$	GJ	$	GJ	$	GJ
DEPRECIATION	2.375	0.1238	0.414	0.01862	0.229	0.0185	0.044/km	0.00512/km
REPAIRS AND MAINTENANCE[f]	) 5.00[e]	0.0294	) 0.45[e]	0.00808	0.2189	0.0227	0.0110/km[g]	
LUBRICANTS[f]	)	0.00295	)	0.00263				0.00120/km
							0.00568.km	0.0001628[h]
LABOUR	2.30		2.00				0.10/km	
TOTAL PER HOUR	9.68	0.156	2.86	0.02933	0.45	0.0412	0.31 /km	0.00656km

a Sources: Header & Tractor WHEAT SURVEY, Implements WHITMORE & McCHESNEY (unpub.).
b Sources: C.B. Norwood & Co., Andrews & Beaven, Whitmore & McChesney, Habgoods.
c Source: McChesney & Smith (1979).
d Pers. comm., L. Davey.
e Farm Budget Manual ($ repairs)
f Adapted from Whitmore & McChesney (1979)
g Assumed 25% of T.E.S. & Initial Cost Arbitrarily.
h Oil changes 20 Lit/yr 40.7MJ/Lit. ($1.42/Lit.)

i The stock of machinery has a total life of 150 yrs; when combined over the 11 implements at once, the average life of the stock of machinery is 13.64 yrs. With a total life of 13650 hrs, on average the stock of implements can provide 1000 hrs per annum. Because of the need for duplication of operations some implements may be required simultaneously. This study assumes that the potential of 1000 hrs can not be fully used, and that actual use of implements is tied to the actual use of tractors (i.e. 400 hrs per annum).

Table I.2

The Life, Energy Sequestered and Initial Costs of Implements

Implement	Life	GJ Energy ES	GJ Energy R&M	Initial Cost $	Initial Cost Year
Baler	1000 hrs (15 yrs)	119.0	26.7	3760	1978
Mower	550 hrs (12 yrs)	30.7	8.3	1398	1978
Harrow 4 leaf	1500 hrs (20 yrs)	9.3		25	1975
Plough	1500 hrs (5 yrs)	67.8	78.3	220	1975
Roller	1500 hrs (15 yrs)	88.97	45.7	250	1975
Drill	1600 hrs (12 yrs)	57.5	40.7	2724	1978
Disc	1000 hrs (15 yrs)	41.7	17.6	180	1975
Cultivator	1000 hrs (13 yrs)	24.4	43.5	1268	1978
Sprayer	1500 hrs (15 yrs)	8.9[a]		293	1975
Rake	1500 hrs (15 yrs)	32.6	5.2	1198	1978
Grubber	1000 hrs (13 yrs)	24.4[b]	43.5	150	1975
	13650 hrs 150 yrs				

a No estimate was available for a sprayer - so a proxy of 14 MJ per $1 (1978) was used. This figure was suggested by Whitmore and McChesney for repairs and maintenance. It has been used here for total energy sequestered.

b It assumed that the grubber has the same E.S. as the cultivator.

Note: These implements have been aggregated for the sole purpose of maintaining the simplicity of the model. For financial calculations, 1975 is taken as the base year. A deflator was derived from a price index for tractors and machinery (NZ Department of Statistics, 1979:82). This was 9.2 per cent discounting 1978 dollars back to 1975 and initial costs can be aggregated over all implements in constant 1975 dollars. Initial cost is used for depreciation calculations.

Sources: i. Whitmore, W. and I.G. McChesney (unpublished).

ii. Lincoln College Accounts Ledger entries.

APPENDIX II

Cultivations

Table II.1

Cultivation Programme

CULTIVATION HOURS INPUT PER HECTARE	SHEEP		WINTER WHEAT				SPRING WHEAT								BARLEY	
	1	2	1A	1B	2A	2B	1A	1B	2A	2B	3A	3B	4A	4B	1A	1B
Plough																
Drill			0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706
Disc							1.2345				1.2345					
TOTAL HEAVY HOURS			2.356	0.706	0.706	0.706	3.59	0.706	0.706	0.706	3.59	0.706	0.706	0.706	0.706	0.706
Vibratil			0.494	0.494	0.494		0.988	0.494			1.482	0.988			1.482	0.988
Roll											0.412	0.412			0.823	1.234
Grub			0.494	1.482					0.494				0.494		1.482	1.482
Bale															0.533	0.533
TOTAL MEDIUM HOURS			0.988	1.976	0.494		0.988	0.494	0.494		1.4	0.906	0.494		4.32	4.2375
Spray			0.206	0.412	0.206	0.617	0.206	0.412	0.412	0.617	0.206	0.412	0.412	0.617	0.206	0.206
Mow																
Spread			0.096	0.507	0.096	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.507	0.096	0.507
Harrow									0.494	0.707				0.706		
Shifting Irrigation											1.30	1.30	1.30	1.30		
Shifting Fences [c]																
TOTAL LIGHT HOURS	3.87 [b]	1.55 [b]	0.302	0.819	0.302	1.124	0.713	0.919	0.919	1.124	1.713	2.219	2.219	2.424	0.302	0.713

CULTIVATION HOURS INPUT PER HECTARE	PEAS		TICKBEAN		RYEGRASSES			FORAGE CROPS				GREENFEED		LEGUMES/PASTURE				
	SEED	FREEZE	AUT.	SPRING	TAMA	MAN.	TAMAS	BEET	KALE	KALE2	GRAPE	MAIZE	OATS	CLOVER	LUC.1	LUC.2	PAST1	PAST2
Plough			1.65	1.65				1.65	1.65	1.65					0.236	0.236		
Drill	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.706	0.101	0.101		
Disc												0.617						
TOTAL HEAVY HOURS	0.706	0.706	2.356	2.356	0.706	0.706	0.706	2.356	2.356	2.356	0.706	1.323	0.706	0.706	0.337	0.337		
Vibratil	0.988	1.482			0.988	0.494	0.988	1.482			1.482				0.07	0.07		
Roll	0.412	0.412			1.2345	0.412	0.823	0.412			0.823			0.412	0.412	0.412	0.412	0.412
Grub		1.482	1.482	1.482	1.976	0.988	2.47		2.47	2.47	1.48	0.494						
Bale	0.488	0.13			0.717	0.25	0.727									0.8		0.333
TOTAL MEDIUM HOURS	1.889	3.506	1.482	1.482	4.915	2.144	5.01	1.894	2.47	2.47	3.787	0.494		0.42	0.42	1.219	0.411	0.745
Spray	0.412	0.206	0.206	0.412	0.206	0.206	0.206	0.206	0.617	0.617	0.206	0.206		0.412	0.206	0.206	0.206	0.206
Mow														0.617		1.2345		0.617
Spread	0.096	0.096	0.096	0.096	0.507	0.507	0.096	0.507	0.096	0.096	0.096	0.507		0.507	0.507	0.507	0.507	0.507
Harrow			0.404						0.494	0.494								
Shifting Irrigation		1.30		1.30	1.30			1.30	1.30	1.30	1.30			1.30	1.30	1.30	1.30	1.30
Shifting Fences [c]								1.16	1.16	1.16	1.16	1.16	1.16					
TOTAL LIGHT HOURS	0.508	1.602	0.796	1.808	2.013	0.713	0.302	3.173	3.173	3.173	2.762	1.873	1.16	2.836	2.013	3.247	2.013	2.63

a Based on rates of work observed on the mixed cropping farm by Clark (1978) and subdivided into three work rate categories for the MF165 tractor (based on fuel consumption by operation type).

b Feeding out based on Clark's fuel use figure divided per head by the number of sheep on the farm at that time.

c Fence shifts took 95 litres for 18 ha forage - 5.28 litres/ha, and therefore at 454 litres/ha, takes 1.16 tractor hours.

Notes on Cultivation Hours Input Table and Fuel Use

1. In one season, the seed dryer used 1228 litres of diesel fuel to dry 25.604 tonnes of ryegrass seed, or 47.96 litres per tonne. This figure is applied to assumed yields for the three ryegrass crops.

2. Lucerne establishment cultivation costs are spread over seven years for gross margin calculations.

3. Pasture follows white clover and ryegrass and requires no establishment.

4. Baling hours are based on Clark's (1978) survey estimate of 300 bales per hour. This rate is applied to the various hay crops which yield different quantities per hectare as observed and recorded in the Farm Bulletins.

5. Spreading requirements (topdressing) are assumed fixed for lime as an annual average of occasional applications.

6. Irrigation shifting is assumed as follows: Clark (1978) estimated 400 litres of diesel was used for irrigation shifting. This involved a light workload and the tractor thus uses 4.54 litres per hour. This gives 88 tractor hours spent in shifting irrigation on the irrigated area, 68 hectares in total. Thus shifts require 1.3 hours per hectare.

7. Assumes rates of work are from Clark (1978:4). For the MF 165 tractor these are assumed as typical for the purposes of the model and are given below by operation.

Table II.2

Work Rates by Operation for an MF 165 Tractor

Operation	ha/hr
Plough	0.607
Drill	1.417
Disc	1.62
Vibratil/grub (and harrow)	2.025
Roll	2.43
Bale	300 conventional bales per hour
Spray	4.86
Mow	1.215
Spread	2.43

8. Fuel consumption rates also from Clark (1978:5) are shown below.

Table II.3

Fuel Consumption by Farm Machinery

Machine		Consumption
MF 165	Light	4.54 litres/hr
	Medium	7.95 litres/hr
	Heavy	11.36 litres/hr
Claas Dominator		9.08 litres/hr
Bedford 7 ton truck		2.17 km/litre petrol (= 10 mpg)

APPENDIX III

Livestock Feed Supply

Table III.1

Feed Supply of High Quality Forage

QUALITY 1 FEED ONLY (>9MJME/ kgDM)	TOTAL DRY MATTER kg	UTILIS-ATION %	UTILISABLE DRY MATTER kg	FEED VALUE[j] MJ/kg DM	METABOL-ISABLE ENERGY-TOTAL G.J.	SOWING DATE	P1	P2	P3	P4	P5	P6	P7
							YIELD IN EACH TIME PERIOD GJME						
Fodderbeet[a]	15 100	69	10 419	10.4	108.36	Oct.				108.36			
Giant Rape	5 290[b]	65[h]	3 438	12.5	42.981	Late Nov.	21.49	21.49					
Kale	12 000[c]	50[h]	6 000	12.0	72.0	Late Oct.			36.0	36.0			
Kale 2	7 900[c]	72[h]	5 688	12.0	68.256	" "	34.13	34.13					
Tama[d]			4 813	10.0	48.13	April				32.09	16.04		
Manawa			4 813	10.0	48.13	"				32.09	16.04		
Tama Seed			4 813	10.0	48.13	Late April				32.09	16.04		
Greenfeed Oats	3 895[e]	60[h]	2 337	10.2	23.837	Late March				23.84			
Greenfeed Maize	9 400f	68	6 392	10.0	63.92	Early Nov.		15.04	15.04				
White Clover	2 602	50	1 300	10.0	13.00	Oversow late Nov.				3.25	6.50	3.25	
Lucerne 1	15 000[g]	50[i]	7 500	11.2	84.0	Sep-Oct.	4.66	4.28	13.66		7.45	49.31	5.14
Lucerne 2	6 500	50[i]	3 250	11.2	36.4	" "			13.66		7.45	15.29	
Pasture 1	10 000[g]	50[i]	5 000	10.0	50.0	Old Clover +	2.15	2.23	10.80	2.35	4.71	25.87	1.90
Pasture 2	6 942	50[i]	3 471	10.0	34.71	Ryegrass paddocks	2.15	2.23	10.80	2.35	4.71	10.57	1.90

a Seafield Canterbury (Stephen, 1973).

b All Rapes in field test yielded on average this amount (Stephen, 1973).

c Drew, K.R. et al (1974).

d Ryegrass yields from Farm Budget Manual (1978) workings.

e Scott, W.R. (1978).

f McDonald, J.R.C. et al (1977).

g Pers. comm. - an estimate from Vartha, D.S.I.R. (1978).

h Scrimgeour, F.G.S. (1978).

i Thomson, W.A. and K.T. Jagusch (1976).

j Farm Budget Manual.

Note: Pasture and Lucerne periodic yields determined from the distributions given in Winchmore and Ashley Dene grazing trials.

Table III.2

The Supply of Conserved, Lower Quality Hay and Straw

Feed Supply/ha	Mean No. Bales[a]	Feed Weight (tonnes)	% DM[b]	Tonnes DM	MJ/kg[b]	GJME[c]	Time Period
Barley	160	3.6	86	3.1	6.7	20.8	P1
Seed Peas	146	3.3	90	2.97	8.8	26.14	P1
Freezing Peas	39	0.9	90	0.81	8.8	7.13	P6
Tama	215	4.8	86	4.13	7.1	29.32	P7
Manawa	75	1.7	86	1.46	7.1	10.37	P7
Tamaseed	218	4.9	86	4.21	7.1	29.89	P7
Lucerne 2	150+90	5.4	90	4.86	8.8	26.73 +16	P2 P6
Pasture 2	100[b]	2.25	85	1.91	8.0	15.3	P6

a Half tonne bales hold (at 22.5 kg per bale on average) 22.2 conventional bales. These bales numbers are mean observed yields from previous seasons.

b Farm Budget Manual, Technical 1977.

c Gigajoules of Metabolisable Energy.
Note: Wheat straw was assumed to be too low in metabolisable energy per unit to be included as a feed item. Other crop residues, such as stubble from wheat, barley, peas, clover and ryegrass have not been evaluated in this study.

APPENDIX IV

The Energy Requirements of Irrigation on the Mixed Crop Farm

PUMP RATING:[a]

INPUT	15 kw	=	54 MJ
OUTPUT	250 gallons per minute	=	68.1 m^3/hr
		and	0.8 MJ/m^3

1 hectare centimetre = 10 000 m^2 x 0.01 m

= 100 m^3

using therefore 0.8 x 100 = 80 MJ of electrical energy

This takes $\frac{80}{54}$ hours to apply or 1.48 hours.

1 hectare cm (10 mm)	1.48	hours	application	80 MJ
1 hectare .75 cm (7.5 mm)	1.11	"	"	60 MJ
1 hectare .5 cm (5 mm)	0.74	"	"	40 MJ
1 hectare .25 cm (2.5 mm)	0.37	"	"	20 MJ

a Personal communication with Harvins Ltd and B. Scott.

Table IV.1

Indirect Energy Requirements of Irrigation on the Mixed Crop Farm

Item[a]	Weight kg	MJ Unit Energy[b]	GJ Total E.S.
SPRAYLINE 5" x 411.5 m, aluminium	872.34	45	39.255
ANGLETOW pressed steel wheels every 12.2 m	439.28	48.5	21.305
SUBMAIN 18.29 m x 5" thick aluminium	38.78	45	1.745
HYDRANTS 17 + outlets	579.7	90	50.173
914.4 m x 6" asbestos concrete pipe	1389.9	2.2	3.058
WELL DRILLING		500/m	19.355
WELL STEELCASING 8" x 38.71 m	1587	35	55.545
STAINLESS STEEL SCREEN 6" x 6.4 m	64	27.1	1.734
PUMP			47.2
TOTAL ENERGY SEQUESTERED			241.37

a Peter Carron, N.Z.A.E.I. from farm plans.

b Dawson, S. (R.S. Berry and M. Fells).

APPENDIX V

Sprays: Application, Energy Requirement and Price Coefficients

The paucity of energy requirements data allowed only a simplified treatment of spray applications. For this reason, sprays costs are modelled using only one price, a weighted average of the prices of sprays used in the 1977 season. Application rates used in the model can be calculated from gross margins data by applying the estimated average factor price of $5.20 per litre (or per kilogram). The price is representative of prices paid by Canterbury farmers and is derived from the Lincoln College Farm Budget Manual (Financial, 1978).

Data specifying the energy requirements separately for solid and liquid sprays are given in Dawson (1978) but the coefficients given make no account of type or concentration of the spray. Disaggregation of spray types is therefore impossible. A weighted average energy requirement coefficient is used for all sprays; by far the majority of sprays used are purchased in liquid form. The solid sprays that are used have a similar energy requirement per kilogram to that per litre of liquid sprays, and so one average energy requirement coefficient is used to represent all spray groups (133 MJ per litre, or kilogram).

APPENDIX VI

Fertilizers : Application, Energy Requirement and Price Coefficients

Table VI.1
Fertilizer Application Rates

	Nitrogen Sulphate of Ammonium	Nitrogen Superphosphate	30% K, Pea, Lucerne Superphosphate	Turnip and Rape Superphosphate	Flowmaster Superphosphate
	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
AWheat 1A					125
AWheat 1B	83.3[a]				125
AWheat 2A					250
AWheat 2B	83.3				250
SWheat 1A	83.3				250
SWheat 1B	83.3				250
SWheat 2A	83.3				250
SWheat 2B	83.3				250
SWheat 3A	83.3				250
SWheat 3B	83.3				250
SWheat 4A					250
SWheat 4B	83.3				250
Barley 1A					250
Barley 1B	83.3				250
Autumn Sown Tick Beans		250			
Spring Sown Tick Beans		250			
Freezing Peas			250		
Seed Peas					125
Forage Fodderbeet		125			
Forage				375	
Giant Rape				250	
Forage Kale, Late Grazed				250	
Forage Kale, Early Grazed				250	
Greenfeed Oats					250
Tama Ryegrass	250	250			
Manawa Ryegrass	250	250			
Tama Ryegrass Seed	125	250			
White Clover, Irrigated			250		
White Clover			250		
Lucerne, Grazed Only	125	250			
Lucerne, Hay and Graze		250			
Pasture, Grazed Only					300
Pasture, Hay and Graze					300

[a] This application represents 250 kg of ammonium sulphate on one-third of spring and second cereal areas, as observed in Farm Bulletin Data.

Sources: Farm Bulletins, personal communication with the farm's management.

Table VI.2

The Energy Requirements and Prices of Fertilizers.

GJ per 1000 kg(t)	Urea	Ammonium Sulphate[c]	Nitrogen Super-phosphate	Turnip and Rape Super-phosphate	Super-phosphate[c]	Pea and Lucerne Fertilizer	30% Potash Super-phosphate
Nitrogen Content			6%	2%			
Energy Required[a]			4320 MJ	1440 MJ			
Phosphorus Content			6%	6%		6%	6%
Energy Required			108 MJ	108 MJ		108 MJ	108 MJ
Potash Content						14%	14%
Energy Required						1358 MJ	1358 MJ
Sulphur Content			14%	10%		7%	10%
Energy Required			742 MJ	530 MJ		371 MJ	371 MJ
Total Energy GJ/t	34.0	15.0	5.17	2.08	1.8	1.84	1.84
$/t[b]	186.05	104.05	67.83	57.35	51.00	70.65[d]	62.55[d]
$/GJ	5.48	6.94	13.12	27.57	28.33	38.40	33.99

a Assumed Nitrogen requires 72 MJ/kg (Dawson, 1978).

b These prices are after subsidy and spreading bounty of $22.50 and $2.50 respectively. Farmers bags prices are used.

c Dawson (1978:34).

d The model combines these two fertilizer groups using one average price of $66.46 per tonne as an approximation of the prices of both.

APPENDIX VII

Gross Margins for Sheep Enterprises

1. SHEEP 1. A 50 ewe flock with one ram. Lambing percentage is 93, deaths are 5 percent, culls are 5 percent, annual wool clip is four kilograms per head. As defined, one unit would produce 46.5 lambs of which 23 wethers are sold.

Culling programme -	Two tooth culls	7.5
	Five year culls	8
	Culls to works	4
	Annual culls	19.5

Direct Costs

Shearing @ $32/100		16.32
Tup crutch		6.50
Main crutch		7.50
Tags, docking, footrot		5.50
Woolshed expenses		5.61
Stockselling charges		2.32
Drench x 2	0.81 litres	9.69
Lamb drench x 3	0.56 litres	3.72
Vaccine	0.258 litres	8.77
Dips, ewes + 0.67 lambs	0.49 litres (Diaz-o-spray)	10.96
Cartage 46.5 sheep - 30 km		15.90
Wool cartage		5.23
Feeding out - 50 hrs total[a] @ $3.20		161.82
Interest 51 x 14.00 @ 10%		71.40
		321.24

Total Revenue

Two tooth culls	7.5 @ $15.00	112.50
Five year culls	8 @ $10.00	80.00
Culls to works	4 @ $9.00	36.00
Lamb Sales	23 @ $10.35	238.05
Wool sales - $1.60 x 51		326.40
		792.95

a Assumed feeding out takes half an hour of man and machine time per day, and is required for 100 days during winter.

GROSS MARGIN 533.11[a]

Feed Demand

GJ feed demanded by the flock[b]:

			Quality 1 ≥ 9 MJ/kg DM	Quality 2 < 9 MJ/kg DM
Period 1, starting on	Feb 1st	11 days	0	5.620
Period 2, " "	Feb 12th	17 "	0.160	8.500
Period 3, " "	March 1st	101 days	42.504	
Period 4, " "	June 10th	65 "	31.740	8.54
Period 5, " "	Aug 14th	123 "	20.515	0.276
Period 6, " "	Sept 14th	123 "	84.365	22.66
Period 7, " "	Jan 15th	17 "	0	8.66

2. SHEEP 2. A 20 hogget unit to utilise excess feed between February and October 14th. Assumed liveweight gain is 100 grams per day necessitating minimum feed quality of 9.2 MJ ME per kgDM. The initial liveweight of the hoggets is 13 kilograms.

<u>Direct Costs</u>

Shearing	6.40
Tags, docking, footrot - 11c/head	2.20
Woolshed	2.20
Drench x 2, 8cc's/dose - 0.32 litres	3.876
Dip - 12 c/head (buys 0.03 litres)	2.40
Vaccine - 0.05 litres	1.79
Feeding out, 34 hrs total	107.88
Buy stock @ 13 kg = $9.00 x 20	180.00
Wool cartage	1.44
Interest	16.20
	324.39

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a The profitability of the sheep enterprises is actually lower than the indicated gross margins since the costs of producing the feed are excluded from this calculation. The model however, treats sheep and feed production as interdependant subsystems, taking into account all costs incurred.

b These figures incorporate increasing feed intake of growing lambs and the varying metabolisable energy required by ewes depending on time within the breeding cycle (pregnancy, lactation, etc). Also included is the feed requirements of one ram.

<u>Total Revenue</u>

Wool sales - 4 kg/head \$1.70	136.00
Sell hoggets - 40 kg, 33.3 c/kg (intervention price)	266.40
(Sell hoggets - 40 kg, 40 c/kg	320.0)
	402.40
GROSS MARGIN	78.11
(or, at 40 c/kg)	131.61

Feed Demand [a]

First 100 days, hoggets require 10 MJ metabolisable energy per day; the next 100 at 12.5 MJ and the subsequent period, to sale, at 14.6 MJ.

P1 2200 MJ ME of Quantity 1 feed
P2 3400 " " " " " "
P3 21650 " " (72x10x20) + (29x12.5x20) of Quantity 1 feed
P4 16250 " " (65x12.5x20)+ " " " " " "
P5 8800 " " (6x12.5x20) + (25x14.6x20)" " " "
P6 9052 " " (31x14.6x20) to sale " " " "

a Products in parentheses represent: (no. of days in period, metabolisable energy demand and number of hoggets).

Sources: Lincoln College Farm Budget Manual, Financial (1978)
Ministry of Agriculture and Fisheries, Feed Budgeting (1976).

APPENDIX VIII

Net Revenue by Crop Type

CROP	Autumn Wheat			
DIRECT COSTS	1A	1B	2A	2B
	$	$	$	$
i. Machinery				
Running Costs				
@ $2.95/tractor hour	3.65	15.49	4.43	5.40
@ $0.66/implement hour	2.41	3.47	0.99	1.21
@ $9.78/harvester hour	9.66	9.66	9.66	9.66
@ $6.46/irrigation hour				
ii. Fuel				
Harvester fuel @ 9.08 litres/hour	1.23	1.23	1.23	1.23
Tractor fuel				
heavy @ 11.36 litres/hour	3.69	1.11	1.11	1.11
medium @ 7.95 litres/hour	1.08	2.17	0.54	
light @ 4.54 litres/hour	0.19	0.51	0.19	0.70
Truck petrol @ 3.63 litres/tonne	4.04	3.98	3.53	3.55
iii. Chemicals				
Fertiliser	6.37	14.12	12.74	20.48
Spray	33.41	41.72	52.31	61.17
Lime	3.125	3.125	3.125	3.125
iv. Cartage				
Off Farm @ $2.36/tonne	12.68	12.49	11.08	11.14
On Farm @ $1.77/tonne to silo	7.96	7.61	6.55	6.37
v. Seed	21.00	21.00	21.00	21.00
vi. Total Handling, Storing, Selling, Certification and Purity				
Sacks				
TOTAL DIRECT COSTS	107.37	137.69	128.49	146.15
REVENUE				
Yield tonnes/hectare	4.5	4.3	3.7	3.6
TOTAL REVENUE	540.00	516.00	444.00	432.00
NET REVENUE	432.63	378.31	315.51	285.86

APPENDIX VIII

Net Revenue by Crop Type

CROP	Spring Wheat			
DIRECT COSTS	1A	1B	2A	2B
	$	$	$	$
i. Machinery				
Running Costs				
@ $2.95/tractor hour	15.61	6.25	6.25	5.40
@ $0.66/implement hour	3.49	1.40	1.72	1.67
@ $9.78/harvester hour	9.66	9.66	9.66	9.66
@ $6.46/irrigation hour	47.80	47.80	47.80	47.80
ii. Fuel				
Harvester fuel @ 9.08 litres/hour	1.23	1.23	1.23	1.23
Tractor fuel,				
heavy @ 11.36 litres/hour	5.63	1.11	1.11	1.11
medium @ 7.95 litres/hour	1.08	0.54	0.54	
light @ 4.54 litres/hour	0.45	0.58	0.58	0.70
Truck petrol @ 3.63 litres/tonne	3.88	3.51	3.28	2.98
iii. Chemicals				
Fertilizer	20.48	14.12	20.48	20.48
Spray	33.38	50.07	52.15	61.70
Lime	3.125	3.125	3.125	3.125
iv. Cartage				
Off Farm @ $2.36/tonne	12.18	11.02	10.29	9.35
On Farm @ $1.77/tonne to silo	7.08	6.19	5.66	4.96
v. Seed	31.5	31.5	31.5	31.5
vi. Total Handling, Storing, Selling, Certification and Purity				
Sacks				
TOTAL DIRECT COSTS	148.78	40.31	150.70	153.87
REVENUE				
Yield tonnes/hectare	4.0	3.5	3.2	2.8
TOTAL REVENUE	480.00	420.00	384.00	336.00
NET REVENUE	331.22	279.69	233.30	182.84

APPENDIX VIII

Net Revenue By Crop Type

CROP	Spring Wheat			
DIRECT COSTS	3A	3B	4A	4B
	$	$	$	$
i. Machinery Running Costs				
@ $2.95/tractor hour	19.97	16.17	10.09	9.24
@ $0.66/implement hour	3.57	2.76	2.26	1.67
@ $9.78/harvester hour	9.66	9.66	9.66	9.66
@ $6.46/irrigation hour	47.80	47.80	47.80	47.80
ii. Fuel				
Harvester fuel @ 9.08 litres/hour	1.23	1.23	1.23	1.23
Tractor fuel				
heavy @ 11.36 litres/hour	5.63	1.11	1.11	1.11
medium @ 7.95 litres/hour	1.54	0.99	0.54	
light @ 4.54 litres/hour	1.07	1.39	1.39	1.52
Truck petrol @ 3.63 litres/tonne	4.04	3.66	3.34	3.17
iii. Chemicals				
Fertilizer	20.48	20.48	12.74	20.48
Spray	41.72	52.15	52.15	61.17
Lime	3.125	3.125	3.125	3.125
iv. Cartage				
Off Farm @ $2.36/tonne	12.68	11.49	10.48	9.95
On Farm @ $1.77/tonne to silo	7.43	6.55	6.02	5.84
v. Seed	31.50	31.50	31.50	31.50
vi. Total Handling, Storing, Selling, Certification and Purity				
Sacks				
TOTAL DIRECT COSTS	211.45	210.07	193.44	207.47
REVENUE				
Yield tonnes/hectare	4.2	3.7	3.4	3.3
TOTAL REVENUE	504.00	444.00	408.00	396.00
NET REVENUE	292.55	233.93	214.56	188.53

APPENDIX VIII

Net Revenue by Crop Type

CROP	Barley		Tickbeans	
DIRECT COSTS	1A	1B	Tick-bean	Tick-bean
	$	$	$	$
i. Machinery				
Running Costs				
@ $2.95/tractor hour	20.59	16.69	12.21	16.66
@ $0.66/implement hour	4.61	3.73	3.06	2.87
@ $9.78/harvester hour	9.78	9.78	21.55	21.55
@ $6.46/irrigation hour				119.51
ii. Fuel				
Harvester fuel @ 9.08 litres/hour	1.25	1.25	2.76	2.76
Tractor fuel				
heavy @ 11.36 litres/hour	1.11	1.11	3.69	3.69
medium @ 7.95 litres/hour	4.74	4.65	1.63	1.63
light @ 4.54 litres/hour	0.19	0.45	0.19	1.13
Truck petrol @ 3.63 litres/tonne	4.14	4.00	3.80	4.20
iii. Chemicals				
Fertilizer	12.74	20.48	16.96	16.96
Spray				
Lime	3.125	3.125	3.125	3.125
iv. Cartage				
Off Farm @ $2.36/tonne	12.99	12.55	11.93	13.18
On Farm @ $1.77/tonne to silo	7.96	7.43		
v. Seed	19.50	19.50	53.20	60.23
vi. Total Handling, Storing, Selling, Certification and Purity				
Sacks				
TOTAL DIRECT COSTS	102.73	104.75	134.11	267.48
REVENUE				
Yield tonnes/hectare	4.5	4.2	3.9	4.4
TOTAL REVENUE	472.50	441.00	629.00	704.00
NET REVENUE	369.77	336.25	494.89	436.52

APPENDIX VIII

Net Revenue by Crop Type

CROP	Peas		Forage Crops	
DIRECT COSTS	Watties	Seedpea	F.Beet	Grape
i. Machinery	$	$	$	$
Running Costs				
@ $2.95/tractor hour	22.02	14.02	21.90	21.40
@ $0.66/implement hour	4.07	3.14	3.28	3.16
@ $9.78/harvester hour	9.78	9.78		
@ $6.46/irrigation hour	119.51		33.46	47.50
ii. Fuel				
Harvester fuel @ 9.08 litres/hour	1.25	1.25		
Tractor fuel,				
heavy @ 11.36 litres/hour	1.11	1.11	3.69	1.11
medium @ 7.95 litres/hour	3.85	2.07	2.08	4.15
light @ 4.54 litres/hour	1.00	0.32	1.99	1.73
Truck petrol @ 3.63 litres/tonne	4.30	2.15	0.90	0.67
iii. Chemicals				
Fertilizer	16.96	6.37	29.98	14.33
Spray	5.21	20.86	51.91	23.06
Lime	3.125	3.125	3.125	3.125
iv. Cartage				
Off Farm @ $2.36/tonne	13.50	6.75	2.80	2.10
On Farm @ $1.77/tonne to silo				
v. Seed	105.60	90.75	2.00	3.90
vi. Total Handling, Storing, Selling, Certification and Purity	38.13	38.13		
Sacks		15.75		
TOTAL DIRECT COSTS	311.32	216.18	157.11	125.09
REVENUE				
Yield tonnes/hectare	4.5	1.77		
TOTAL REVENUE	832.00	274.35		
NET REVENUE	520.68	58.18		

APPENDIX VIII

Net Revenue by Crop Type

CROP	Forage Crops			Ryegrass
DIRECT COSTS	Kale	Kale2	G.F.Oats	Tama
	$	$	$	$
i. Machinery				
Running Costs				
@ $2.95/tractor hour	23.60	23.60	5.50	22.52
@ $0.66/implement hour	3.98	3.98	0.47	4.18
@ $9.78/harvester hour				12.13
@ $6.46/irrigation hour	47.80	47.80		19.12
ii. Fuel				
Harvester fuel @ 9.08 litres/hour				1.55
Tractor fuel,				
heavy @ 11.36 litres/hour	3.69	3.69	1.11	1.11
medium @ 7.95 litres/hour	2.71	2.71		5.39
light @ 4.54 litres/hour	1.99	1.99	0.73	1.26
Truck petrol @ 3.63 litres/tonne	0.67	0.67	0.26	1.30
Dryer				5.14
iii. Chemicals				
Fertilizer	14.33	14.33	12.74	40.21
Spray	51.91	51.91		65.21
Lime	3.125	3.125	3.125	3.125
iv. Cartage				
Off Farm @ $2.36/tonne	2.10	2.10	0.82	4.08
On Farm @ $1.77/tonne to silo				
v. Seed	1.75	1.75	13.50	33.85
vi. Total Handling, Storing, Selling, Certification and Purity				71.23
Sacks				
TOTAL DIRECT COSTS	157.66	157.66	38.26	291.93
REVENUE				
Yield tonnes/hectare				0.8
TOTAL REVENUE				400.75
NET REVENUE	-157.66	-157.66	-38.26	108.82

APPENDIX VIII

Net Revenue by Crop Type

CROP	Pasture Seeds			
DIRECT COSTS	Manawa	Tama Seed	White Clover	White Clover
i. Machinery	$	$	$	$
Running Costs				
@ $2.95/tractor hour	10.51	17.75	11.66	7.82
@ $0.66/implement hour	2.53	3.97	1.75	1.75
@ $9.78/harvester hour	12.13	12.13	16.14	15.14
@ $6.46/irrigation hour			47.80	
ii. Fuel				
Harvester fuel @ 9.08 litres/hour	1.55	1.55	2.06	2.06
Tractor fuel				
heavy @ 11.36 litres/hour	1.11	1.11	1.11	1.11
medium @ 7.95 litres/hour	2.35	5.50	0.46	0.46
light @ 4.54 litres/hour	0.45	0.19	1.78	0.96
Truck petrol @ 3.63 litres/tonne	1.18	1.26	1.02	1.02
Dryer	4.34	5.29		
iii. Chemicals				
Fertilizer	40.21	28.58	16.61	16.61
Spray	65.21	44.31	62.58	62.58
Lime	3.125	3.125	3.125	3.125
iv. Cartage				
Off Farm @ $2.36/tonne	3.70	3.95	3.20	3.20
On Farm @ $1.77/tonne to silo				
v. Seed	23.64	17.84	6.63	6.63
vi. Total Handling, Storing, Selling, Certification and Purity	64.88	74.65	74.61	66.55
Sacks				
TOTAL DIRECT COSTS	236.92	221.21	250.49	190.03
REVENUE				
Yield tonnes/hectare	0.656	0.776	0.416	0.370
TOTAL REVENUE	328.00	388.36	582.02	519.40
NET REVENUE	91.08	167.15	331.53	329.37

APPENDIX VIII

Net Revenue by Crop Type

CROP	Lucerne 1 $	Lucerne 2 $	Past. 1 $	Past. 2 $
DIRECT COSTS				
i. Machinery				
Running Costs				
@ $2.95/tractor hour	8.15	14.17	7.15	9.96
@ $0.66/implement hour	0.965	2.31	0.74	1.37
@ $9.78/harvester hour				
@ $6.46/irrigation hour	93.67	93.67	93.67	93.67
ii. Fuel				
Harvester fuel @ 9.08 litres/hour				
Tractor fuel				
heavy @ 11.36 litres/hour	0.53	0.53		
medium @ 7.95 litres/hour	0.46	1.34	0.45	0.81
light @ 4.54 litres/hour	1.26	2.03	1.26	1.65
Truck petrol @ 3.63 litres/tonne	0.71	0.67	0.71	0.71
iii. Chemicals				
Fertilizer	40.21	16.96	15.30	15.30
Spray	20.98		20.98	
Lime				
iv. Cartage				
Off Farm @ $2.36/tonne	2.23	2.10	2.23	2.23
On Farm @ $1.77/tonne to silo				
v. Seed	5.00	6.84		
vi. Total Handling, Storing, Selling, Certification and Purity				
Sacks				
TOTAL DIRECT COSTS	174.17	140.62	142.49	125.70

APPENDIX IX

Relative Input Price Response to Rising Fuel Prices

The problem is to determine for the longer term the movements in input prices as a direct consequence of energy price increases. Many inputs to New Zealand farms are manufactured overseas and the responsiveness of their prices to rising energy price is largely determined outside this country. For this reason, data from the United States is the basis for one method chosen to estimate input price movements.

Three methods have been used to estimate these movements. The first is an input-output study by Wright (1974) which shows for each of 363 sectors in the U.S. economy the energy inputs per dollar of sector output. By comparing the fertilizer producing sector with that which produces farm machinery, it is argued that if one includes twice as much energy input per dollar output as the other, the first will be twice as responsive to energy price increases. Thus all farm inputs are ranked by relative response, with petroleum and petroleum products taking unit value. As petroleum increases in price, the other farm inputs change price also in known proportions. However, this study is not used exclusively because it is based on the 1963 U.S. Inter-Industry Survey which does not take account of subsequent technology changes or substitutions. Wright's original figures are converted to MJ/NZ$1978 by applying input price deflators for each separate farm input group.

The second method used, takes the energy requirements for inputs to New Zealand agriculture calculated by Dawson and expresses these energy inputs per dollar of 1978 retail price (ex price subsidy). Dawson's energy requirements figures include all energy sequestered in production and distribution of inputs up the farm gate and this therefore includes all transport costs. Energy intensities of fuel and petroleum products are not included in this because Dawson calculated the energy content of fuels (not strictly comparable with measures of energy sequestered in the production of fuel). In order to establish some connection between the price responsiveness of all other inputs to a given change in the price of petroleum and petrol products, the relativity between the energy intensities of fuel and nitrogenous fertilizer from the first method is used as a bench-mark in the second. Other input price responses are given by their relativity with nitrogenous fertilizers.

The third method simply compares the inflation rates of all inputs observed since 1970. This takes into account all of the lagged indirect effects of energy price increases, and includes the impacts of all other inflationary stimuli which thus overemphasizes the responsiveness of input prices (to fuel price). The three methods are compared in Table IX.1.

Table IX.1

Comparison of Price Response Indicators

INPUT	WRIGHT		DAWSON		INFLATION	
	MJ/$[a]	RANK	MJ/$[b]	RANK	INDEX[c]	RANK
All Petroleum	289.5	1		1	7220	1.
Motor Spirit	247.0	0.853		0.853	5475	0.76
Header	20.8	0.072	12.7	0.0224	4151	0.575
Tractor	29.1	0.1006	20.2	0.036	3193	0.442
Implements	25.0	0.0865	23.9	0.042	3443	0.477
Nitrogen-Fertilizer	59.4	0.205	116.0	0.205	4673	0.647
Non-Nitrogen-Fertilizer	60.6	0.21				
Spray	33.8	0.12	26.2	0.0464	3218	0.446
Lime	101.5	0.35	200.0	0.353	2019	0.28
Super-phosphate	78.56	0.27	17.8	0.0315	2814	0.394

a Intensities in Btu/US$1963 are changed using deflators on individual imports prices.

b Prices used exclude subsidies.

c Source: MAF Economics Division (1970 to 1978).

The coefficients (rankings) used to estimate relative price responsiveness are shown in Table IX.2.

Table IX.2

Response Coefficients Adopted

Input	Range	Coefficient
Petroleum and Products	0	1.0
Motor Spirit	0.7-0.8	0.75
Lime	0.2-0.3	0.25
Nitrogen Fertilizers - straight	0.15-0.4	0.2
Nitrogen Fertilizers - in superphosphates	0.03-0.3	0.15
Superphosphates (non nitrogen)	0.03-0.3	0.08
Implements	0.05-0.09	0.07
Tractors	0.04-0.0	0.06
Headers	0.03-0.075	0.05
Sprays	0.045-0.35	0.10

Note: Machinery inputs increase in cost to the farmer through increased repair costs (and fuel) because depreciation expenses and the interest payments are made on the initial cost of the machine, not its replacement value. He will of course, face higher capital costs when he does replace his existing stock of machinery.

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