BOVINE SOMATOTROPIN (bST): AN ASSESSMENT OF POTENTIAL RESPONSE AND PROFITABILITY FOR ADOPTION ON NEW ZEALAND DAIRY FARMS

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ABSTRACT

Administration of the growth hormone bovine somatotropin (bST) is known to increase milk production in lactating cows making the technology attractive for use in commercial dairying. BST a cost reducing and output enhancing technology is used in some countries while others including New Zealand have not approved the use of the hormone. Studies indicate that as a result of bST use by some major dairy producers, low cost or subsidised dairy products could enter international trade to damage competitive positions of other major dairy exporters not adopting the technology. New Zealand's dairy industry is particularly vulnerable to such a situation.

The objectives of the study were to estimate potential response and evaluate the profitability of bST use in New Zealand dairy farms. Response to bST is highly dependent on the level of animal nutrition and most available information is for stall fed cattle. The study attempts to estimate the potential for bST in a pasture based dairy management system in New Zealand.

Twelve sites representative of the major dairying regions of New Zealand were selected. Data on pasture growth rate were compiled from published data or where such data were unavailable were generated through computer modelling. Response to bST was assumed to be a function of pre-grazing herbage mass. Regional bST response were calculated on this basis.

The study assumed a 150 day bST treatment period for seasonal herds in New Zealand. The profitability of bST use was estimated in five 30 day sub periods for the twelve sites used in the study. The incentive to use bST on New Zealand dairy farms is assessed on the basis of a required return to management.

Results reveal that feasibility of bST use in New Zealand dairy farms are closely linked to pasture growing conditions. For the Northland, Bay of Plenty,

Taranaki and Southland sites where pasture growth is consistent, bST use is feasible throughout the 150 day treatment period considered in the study commencing from peak lactation. For the balance of North Island sites which included Waikato, Rangitikei, Manawatu and Wairarapa districts, the drier summer condition and relatively high stocking rates prevailing made bST use feasible only during the first half of the lactation cycle. For the South Island sites excluding the dry Central Otago site, bST could be profitable only during the second half of the lactation cycle because of the colder winters and late spring. The study identifies how bST could be manipulated by the New Zealand dairy farmer to maximize returns.

The findings are that bST could be used selectively to enhance profits on New Zealand dairy farms. If at some stage bST were approved for use in New Zealand, dairy farmers would be aware of the implications. Secondly, it provides a base to survey the attitudes of dairy farmers to know of the likely adoption rates for a better understanding on the effects bST would have on the dairy industry of New Zealand.

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Chapter 1

INTRODUCTION

Milk production technology advanced throughout the twentieth century leading to steady and significant increases in efficiency and economic returns from dairying. These gains are mainly due to herd improvement by controlled animal breeding and better herd health. More recent advances in biotechnology unfold a revolutionary process in agriculture surpassing many years of technology development through conventional research . The emerging new technology is now being recognised as applicable to the dairy industry.

Bovine Somatotropin (bST) is a protein hormone, naturally produced by the anterior pituitary gland in cattle and known to be the key factor controlling efficient milk production in genetically superior cows. The landmark break through in biotechnology has enabled bST to be synthesized through recombinant DNA techniques using bacteria. The exogenously produced bST is similar in its effects to natural bST and when injected into cows, it has the potential to greatly enhance milk production without any apparent harmful effects on health of the cow or changes in the quality of milk.

The potential of bST as a cost-reducing and out-put enhancing technology for dairy management is well documented. Though benefits from bST are known, considerable controversy surrounds its potential use, specially in terms of human and animal health considerations.

The introduction of any new technology goes through an initial period of evaluation and criticism. For instance, previous innovations for the dairy industry, such as artificial insemination, pasteurization, and bulk tanks were not accepted without controversy (Fallert *et al.*, 1991). The sensitivity of the issue of bST has delayed governments approving commercial use of bST. After a long debate, the Food and Drug Administration of the United States of America, in November 1993 approved the use of bST as safe to be used in the dairy industry of the US. The product was marketed for commercial use from February 1994. Despite intense publicity and threats of protests, the US consumers showed no signs of turning away from milk during the first three months of the sale of bST (Lewis, 1994). However, it is still too early to assess the reaction of consumers because little is known about where the milk from treated cows is being sold. Individual States within the US however, have imposed a moratorium on its use. The European Commission's panel of experts on veterinary products approved bST as a safe drug (New Scientist) but the European Council of Ministers are yet to approve its use. BST is already registered for marketing in 14 countries (Bauman *et al.*, 1993) including, Czechoslovakia (Skarda, 1991), India (Fallert *et al*, 1991), South Africa, the former USSR, Mexico, Brazil and Namibia (Chusson, 1991). Many other dairy producing countries, including New Zealand have adopted a "wait and see" policy (Guthrie, 1992), until more is known of the controversial issues.

The period for likely approval of bST for commercial use in any country that is considering its use is uncertain. If in the future some major dairy producers were to adopt this new cost-reducing technology, it may interfere with competitive positions of other countries that do not permits its use. New Zealand, an important dairy producer, has not given pharmacological approval for bST use in the New Zealand dairy industry. However, it is important to understand the effect bST can have on the dairy industry of New Zealand before any decision is being taken for its approval for use.

1.1 Statement of the problem

Studies reported on bST since the latter part of the last decade suggest that substantial increases in milk yields can be obtained by use of bST. The expected milk yield increases are 10 to 30 percent and greatly enhance the productive efficiency of dairy cows. However, the milk response can vary according to the quality of management (Bauman, 1992). The remarkable gains in milk production from bST, caused concern and initiated economic studies in several leading dairy producing countries of the northern hemisphere to assess the potential impact the technology could have on the respective dairy industries (Fallert *et al.* 1987, Geisen *et al.* 1989, Kinnucan *et al.* 1990, Mouchet 1989, Skarda 1991, Schmidt 1989, Trelawny *et al.* 1989, Zeddie *et al.* 1989). Farm level impact studies in the EC give more emphasis to structural changes that may occur on farms because of bST adoption on the basis that milk supply quotas for individual dairy farms limit their capacity to expand production. For the US, a flexible price support mechanism and quota system along with the existing fixed price-support mechanism were used to study the impact of bST at farm level. Many studies indicate that US could potentially be a major exporter of dairy products if bST was adopted (Fallert *et al.*, 1987; Chadee and Guthrie, 1991; Guthrie, 1992).

Since most of New Zealand's the dairy production is exported, New Zealand is in a vulnerable position to any policy changes in other larger milk producing countries, especially EC and US, that might influence the competitiveness of New Zealand in the world market. The US under the Dairy Export Incentive Programme (DIEP) has announced plans for exporting more dairy products in the future (MAF,NZ, 1993), perhaps preparing for the surpluses expected from bST adoption. These trends may result in more dairy produce entering international trade. BST, a cost-reducing and out-put enhancing technology, if approved for use in dairy industries of New Zealand's competitors, can exert influence on the present trends in international trade of dairy products. At present New Zealand enjoys a favourable position in international trade without any price support schemes because of the low cost dairy production technology being adopted. This competitive position could suffer if bST were adopted abroad and not in New Zealand. In such a situation New Zealand could see its market share eroded if its customers turn to relatively cheaper dairy produce from other leading exporters adopting bST. If this situation arises one prospect for reducing the cost of production of New Zealand's dairy products is through the use of bST. Though bST has not been approved for use in New Zealand, because of the importance bST has created in the dairy sphere its likely influence on the dairy industry of New Zealand needs to be appraised.

The impact of bST on the dairy industry of New Zealand depends entirely on the likely adoption of the technology at farm level. New Zealand dairy farmers receive virtually no government assistance and are not bound by production quotas at the farm gate. Their survival depends on efficiency. While operating within this framework the decision to adopt any new technology needs a clear profit driven incentive. The central issue therefore in adopting bST is profitability to the farmer. The absence of information to show the returns to bST use under New Zealand's mainly pasture-based farming conditions leaves a void in the rational decision making process of the farmer.

1.2 Objective

This ex ante study will estimate the returns to adoption of bST under New Zealand dairy farming conditions. The purpose is to get a better understanding of the probable farmer reaction towards the new technology. The likely adoption rates demonstrated by the benefits of bST use to the dairy farmer will serve as a first step towards assessing the impact bST would have on the dairy industry of New Zealand and the external trade of New Zealand's dairy products.

1.3 Outline of the study

Chapter 2 reviews literature on bST and gives an overview of dairying in New Zealand, especially, considering the forage base in relation to climate. Chapter 3 gives a description of a bST trial on cows managed on grazed pasture in New Zealand that formed the basis of this study. Chapter 4 outlines the methodology adopted in the study directed towards the pasture based dairy management system in New Zealand. Chapter 5 estimates a bST response model and forecasts milk production increases and revenues expected on dairy farms giving an indication of incentives for using the technology. Chapter 6 gives a summary of the study, the conclusions that can be drawn from it and suggestions for further research.

Chapter 2

LITERATURE REVIEW

2.1 Introduction and overview

New Zealand systems of dairy production are based almost exclusively on grassland farming (Holmes and Wilson, 1984). Pastures are mainly perennial ryegrass / white clover swards that grow year-round because of favourable climatic conditions. Milk production has long been based on the conversion of pasture into milk by grazing cows. However, during slack periods of pasture production small quantities of silage and hay are fed to cows but with little or no concentrate meals being used (Holmes and Wilson, 1984). The relatively low prices received for milk by the New Zealand dairy farmer leads to an almost complete reliance on grazed pasture as the sole source of feed to the animals. Thus seasonality of pasture production has to be accommodated to optimise herbage utilization and animal performance. The short lactation periods and the lower overall feed intake make dairying a low output industry compared to the US and the EC.

Bovine Somatotropin (bST), a cost-reducing and output enhancing biotechnological product is developed for the dairy industry. The product is being commercially used in a few countries that practice dairying under controlled environments and concentrate feeding systems. Very limited research has been done on the extensive use of bST to pasture based systems as in New Zealand. However, this ex ante analysis is to investigate the likely impact of the new technology on the dairy producers of New Zealand. It is against this background, that the following review of literature will focus on the importance of understanding bST and its influence on milk production and dairy cow performance under the seasonal nature of grassland systems in New Zealand.

In view of the breadth of the subject matter covered, use has been made of existing authoritative reviews of original material to provide an information base. Original references are cited where they are particularly relevant to the discussion.

2.2 Dairy farming in New Zealand

2.2.1 General characteristics

A large proportion of the land area of New Zealand consists of deeply dissected hill country or mountainous terrain with the remaining relatively small area of river and coastal plains being demanded for urban, commercial and cropping uses (Clough *et al.*, 1985). The soil is not particularly fertile, with much of the natural nutrients removed with the clearing of the natural forest cover. The moist and equable climate in New Zealand favours continuous grass growth giving the country an endowment for pastoral production. In addition the historical fact of relatively recent settlement has allowed the development of a specialized farm structure well adapted to achieving modern productive efficiency (Clough *et al.*, 1985).

The natural conditions of the country makes New Zealand dairying predominantly pastoral, with farm management oriented to maximizing use of permanent pasture in the production of animal products. Surplus pasture is used to make hay or silage for winter feed, but generally over much of the country animals can be effectively grazed all the year round with little requirement for supplementary feed or housing. This emphasis of dairying solely on pasture makes milk production seasonal, following pasture growth patterns, rapidly growing from July to peak with the spring flush of pasture growth in October and November and gradually declining through to May when cows are 'dried off'. There is also a small category (about ten percent) of dairy farms close to town centres producing milk all the year round for liquid milk supply. The higher costs incurred on supplementary feed during slack period of pasture growth in winter and the additional labour needed to maintain the herd throughout, increases production costs of town milk supply farms making it unattractive. A higher milk price is offered as an incentive to town milk suppliers but bounded by milk supply quotas.

2.2.2 Dairy farm characteristics and spatial distribution

The North island accounts for about eighty nine percent of dairy farms because of suitable climatic conditions, the larger population and the historical concentration of the dairy industry here. The greatest density of farms are located on yellow-brown loam soils in South of Auckland-Bay of Plenty (41 percent), Taranaki (18 percent) and Northland (11 percent). Smaller concentrations are found in Central Auckland, the yellow-brown soils of Manawatu-Wanganui and

Wairarapa districts; the better soil districts of Nelson and Canterbury, and in Westland with localized deposits of recent loams (Appendix 1).

The structure of New Zealand dairy farms has changed over the years to fewer but larger farms (Clough *et al.*, 1985). There is a progressive decline in the number of dairy farms from 29,095 in 1960 to 14,597 in 1993/94. Conversely, the average herd size has increased from 75 cows in 1963 to 187.5 in 1993/94
The restructuring of New Zealand farms into larger, more efficient units demanded use of new technology such as herringbone and rotary milk sheds, better pasture management, artificial breeding and disease prevention to raise the output per man, per animal and per hectare (Clough *et al.*, 1985). Apparently this shift towards larger units is in pursuit of productivity gains. Employing new technological developments can further enhance the productivity gains obtained so far in the New Zealand dairy industry. The latest addition in the line of technological development for the dairy industry is synthetic bST. The proceeding section reviews bST technology.

2.3 Overview of Bovine Somatotropin (bST)

The potential of bST to improve the productive performance of lactating cows was learnt through early experiments in which extracts of the hormone were injected to lactating cows. Research has since established that bST exerts a key role in better partitioning of nutrients towards milk production in genetically superior cows (Bauman *et al.*, 1980, 1989; Bines *et al.*, 1982). However, experimentation on bST was slow due to limited availability of pituitary extracts.

Lately, advances in biotechnology have enabled bST to be produced synthetically making the product available for widespread experimentation and open to commercial use.

Quality of management, mainly feed quality and supply, is a major factor affecting the magnitude of milk response to injected bST. Varied responses ranging from ten to thirty percent increase in milk production have been observed under different management conditions (Bauman *et al.*, 1985; Chillard *et al.*, 1989; Chalupa *et al.*, 1986, Baird *et al.*, 1986; McCutcheon *et al.*, 1989; Peel *et al.*, 1985). Exogenous bST, administered as daily injections or prolonged release formulations must be present every day during the lactation period of the cow to continue an augmented milk response (Chillard *et al.*, 1988; Peel *et al.*, 1987). The best response is achieved when the hormone is administered after peak lactation (McCutcheon *et al.*, 1985). Voluntary intake of food in bST supplemented dairy cows increase after a few weeks of treatment and persists throughout the use of bST (Bauman, 1992). The magnitude of increase in feed intake is in turn dependent on the response in milk yield and the energy density of the diet (Chalupa *et al.*, 1989; Chillard *et al*,. 1988; Peel *et al.*, 1987).

2.3.1 Use of Bovine Somatotropin (bST) under controlled environments

A large part of research conducted on the effects of bST on milk production was on cows managed under controlled environments. When adequate concentrate feeding coupled with other facets of quality management are used yield responses to bST are maximised. Such facets include herd health, milking practices and acceptable environmental conditions, all achievable when animals are housed (Chalupa *et al.*, 1986; Bauman *et al.*, 1985; Elvinger *et al.*, 1988). Use of bST with constant concentrate feeding provide the required energy for greater output and in addition improves the persistency of lactation that pushes the production higher by reducing the normal decline in the latter stages of lactation (Bauman, 1992).

2.3.2 Use of Bovine Somatotropin (bST) in pasture based dairy systems

A limited number of studies have been reported on bST treatment of cows managed on grazed pasture (Brumpy and Hancock, 1955; Peel *et al.*, 1985; Hoogendoorn *et al.*, 1990; McCutcheon *et al.*, 1989; Michael *et al.*, 1990). These studies suggest milkfat response to bST which varies from ten to eighteen percent to be highly dependent on the availability of pasture.

2.3.2.1 Availability of pasture and response to Bovine Somatotropin (bST)

A consistent feature of bST use on cows grazed on pasture is that response (ie., extra milkfat output) varies according to herbage yields (Hoogendoorn *et al.*, 1990), suggesting that bST treatment is strongly influenced by the season. Hoogendoorn *et al.* (1990), conducting their research on a pasture based dairy management system in New Zealand found the greatest response to be in spring, early summer and autumn when the climate is favourable for growth of pasture. Conversely, these authors found response insignificant during the dry summer months when herbage yield is low. Continuous measurement of pasture intake by cows is not reported. However, a relationship is derived between herbage mass offered to cows and response to bST. The response (kg milkfat per cow per day) to bST treatment was observed to be zero when pasture herbage mass dropped below 2000 $kgDMha^{-1}$ indicating that a lower herbage mass does not provide sufficient energy for increased milk output. Evidence from Hoogendoorn *et al.* (1990), confirms that response to bST on cows fed on grazed pasture is positively correlated to herbage yield. Little is known of the nature of response to bST at higher levels of herbage mass, exceeding 3000 $kgDMha^{-1}$. However, natural phenomena would limit intake capacity (ie. biting rate, rumen capacity).

2.3.2.2 Bovine Somatotropin (BST) and feed conversion efficiency

The real economic benefit from bST is the efficiency with which the available pasture is converted to saleable output. Two long term experiments are reported on cows being grazed (Peel *et al.*, 1985; Hoogendoorn *et al.*, 1990). Changes in voluntary intake have not been described in detail because of the difficulties involving measuring intakes of grazing animals. However, Peel *et al.* (1985), reported an 18 percent increase in milk production during the trial period corresponding to a maximum of 14 percent increase in pasture intake. The increase in voluntary intake was observed to be 8 percent in week eight of treatment, increasing to a maximum towards the end of the twenty two week trial period. Hoogendoorn *et al.* (1990), also estimated the voluntary intake of bST treated cows. Though a very small increase in pasture intake in the bST treated group was observed over the control, the difference in intake between the two groups was non-significant. However, they concluded that the net loss in condition score (0.3 condition score units) of the cows treated with bST at the end of the lactation period was not sufficient to explain the increased response to milkfat and suggested that some voluntary intake had occurred. Clearly, the above evidence shows that cows treated with bST will need to be provided with additional pasture to meet the increased demand of lactation. This in turn suggests a need for lower stocking rates to be adopted on farms where bST is used.

2.3.2.3 Bovine Somatotropin (bST) treatment and genetic merit of cows

The response to bST differs with the genetic merit of cows (Michael *et al.*, 1990). In their long term trial using cows of low, medium and high breeding index, the best response was observed in cows of low breeding index followed by medium and high breeding index. The gains observed in cows of low breeding index is about five times larger than the response achieved by cows of high breeding index. The explanation for this difference is that cows of high breeding index are already close to their limits of their ability to use body reserves or consume additional forage in support of lactation. The trial suggests that in grazed cows, selection of animals to be treated based on pretreatment production is a useful means of maximizing the response in fat yield per unit of bST administered. The response by cows of low breeding index from a management point of view allows farmers to gain the benefit of many years selection overnight and in turn these benefits could be turned 'on' or 'off' at will (McCutcheon *et al.*, 1985).

Given the marked improvements in production that occur because of administering exogenous bST much controversy exists among advocates of both producer and consumer interest groups regarding the commercial use of the product.

2.3.3 The controversy over Bovine Somatotropin (bST)

There is disapproval and negative public perception regarding the use of bST. One commonly expressed concern is that the health of animals will be compromised by using the hormone. These critics have postulated that bST supplement of dairy cows lead to mastitis, milk fever, fatty liver, ketosis and chronic wasting as side effects of treatment (Bines and Hart, 1982; Kronfield, 1982, 1987; Fox, 1988).

Consumer advocates express the fears that excessive use of antibiotics on cows treated with bST can contaminate milk and cause reduced resistance in the general population towards viral infections. Others also believe that treatment could affect the quality of milk. In this era of demand for natural products milk from treated cows may be rejected by the consumer as being contaminated with chemicals. Thus there looms a problem of markets for milk from treated cows. Several consumer surveys conducted in the US by Preston *et al*. (1991), Kaiser *et al*. (1992) and McGuirck *et al*. (1992) portend sizeable negative consequences for fluid milk consumption if bST were to be introduced for commercial milk production.

In the United States some believe that because bST allows farmers to produce considerably more milk, surpluses could create a situation of the early

1980's. Others believe that small and medium sized dairies will not be able to compete with the larger counterparts.

These concerns have prompted some dairy producer groups and consumer advocates to call for a ban on the use of bST, even before it was available on the shelves. Despite these adverse claims against bST, the scientific community disputes the arguments as baseless and endorses the safety of the product for humans (Miller, 1992). A statement made by the National Institute of Health technology assessment conference (1992) outlines that meat and milk from bST treated cows are as safe as those from untreated cows. Bauman *et al.* (1993) report that many American medical and scientific groups, the World Health Organization, the Food and Agriculture Organization of the United Nations and regulatory organizations in 30 other countries, now publicly document that food products from bST treated animals are safe for human consumption. Similarly, other scientists state that treating cows with bST does not affect cow health or the quality of milk (Bauman, 1992; McCutcheon and Bauman, 1986, Anderson *et al.*, 1991; Hoogendoorn *et al.*, 1990).

While the debate continues, there are others who feel that education is likely to play an important role in influencing consumer attitudes and perceptions about bST and antibiotics (Kaiser, 1992; Erpelding, 1991).

Despite controversy over bST, research continues to broaden its base on the new technology. For a pasture based dairy management system in New Zealand, research strongly suggests an association between pasture availability and bST response. In view of this association it is necessary also to examine literature on pasture growth and management practices that enhance pasture yields. This will lead to a better understanding of the prospects for improving feed supply in the event of adoption of bST technology in a pasture based dairy management system in New Zealand. Thus the next section reviews herbage accumulation rates and management of pastures in New Zealand.

2.4 Grassland farming systems and seasonality of pasture production in New Zealand

2.4.1 Climatic variation and patterns of pasture growth

Pasture is the main source of feed to dairy cattle in New Zealand and as a result dairying is concentrated more in areas with equable climates providing a reliable pasture production throughout the year (Holmes and Wilson, 1984). Similarly, the performance of livestock industries in New Zealand is affected by a large regional and seasonal variability of pasture production (Baars and Radcliffe, 1990) bringing to light the importance of manipulation of pasture growth and supply as a major component of dairying in New Zealand.

Variability in pasture production due to regional and seasonal patterns was measured in a series of standardized experiments at 20 sites in New Zealand (Radcliffe and Baars, 1986). Pastures in the trials were based on Perennial ryegrass and white clover (Radcliffe, 1974a). According to Korte *et al.* (1987), patterns of pasture production in New Zealand fall into four major environmental categories; warm humid, summer dry, cold humid and cold dry. Radcliffe (1974 a) provides more elaborate version of the climatic variability of thirteen climatic districts (appendix 2). However, not all of the latter classification is important in terms of dairy production.

In general the North Island has very warm to warm summers and mild winters compared to warm to mild summers and cool winters in the South Island. Where pasture production trials have been conducted, it is observed that annual pasture production among North Island sites is greater and much more variable than among South Island sites (Radcliffe and Baars, 1986). There is also evidence of considerable annual pasture yield variation from year to year (Radcliffe and Baars, 1986). This highlights the importance of seasonal and annual pasture yield variability.

2.4.1.1 Seasonal Patterns of pasture production

Rainfall and soil temperature are identified as the major determinants of seasonal variation in pasture production. A close correlation exists between pasture growth during spring and autumn, and soil temperature at 10 cm depth (Radcliffe and Baars, 1986). Spring pasture growth rates at many lowland sites in New Zealand show little variation from year to year (Radcliffe, 1979) but summer growth (December - April) usually shows greatest variation in response to fluctuation in effective rainfall. Sixty percent of the variation in annual yields is accounted for by spring and summer rainfall (Radcliffe and Baars, 1986).

Evidence also suggests that proportionately more pasture growth occurs in winter and less in summers in the North Island than in South Island. Pasture cutting trials in the North Island show a pronounced spring peak of pasture growth followed by lower growth rates over summers followed by an autumn flush of growth. The South Island has a shorter pasture growing season in late spring and early summer. The droughty sites of the South Island has lower growth rates with a spring peak.

The water holding capacity of the soil also affects pasture growth (Radcliffe and Baars, 1986).

2.4.1.2 Grass species and seasonal production

Grass species show different patterns of growth (Radcliffe and Baars, 1986). Subtropical species and clovers are active in the summer while temperate species (ryegrass) are more active in winter and spring.

2.4.2 Pasture management

Pasture management systems most often affect pasture growth rates and yield. There is evidence that a 28 day interval between grazings gain 22 percent more annual production than in 14 day intervals (Baars, 1982).

Ryegrass is the dominant pasture in New Zealand. Studies have been conducted on management of ryegrass that could lead to increases in herbage yields. A high proportion of ryegrass tillers turn reproductive in spring and form seed heads. The effect of management on this process has been studied (Korte, 1984; Da Silva, 1994). All studies agree that seed heads should be removed, but recommendations as to timing varies. Hughes (1983) recommended early removal, while da Silva (1994) showed that summer pasture production was higher following a late control spring management in which seedheads were not removed until after anthesis.

2.5 Pasture yield variability

As discussed in the preceding section there is considerable variation in annual pasture yields at different sites in New Zealand along with year to year variation within a single site. The yield variability at a particular site is caused by changing weather patterns creating uncertainty in pasture production. The primary factor for successful adoption of this new technology will be the ability of farmers to offer sufficient herbage to cows for a bST response. Herbage on offer is in turn a reflection of pasture growth rates, stocking rates and other management decisions. No work has yet been carried out, to determine the likely effect of variability in pasture yields with respect to the probability of success in adopting bST at the different locations of interest. Standardised pasture yield trials are reported for twenty lowland sites in New Zealand (Radcliffe and Baars, 1986) providing base information on average pasture growth rates and yield variability, based on short and medium term trials. However, no long term trials (30 years or more) are reported and there is no attempt made to predict the economic implications of variation in annual pasture production caused by uncertain weather. For sites where pasture growth rate measurements are not known pasture growth modelling is one way of approximating actual values. The next section outlines the efforts made to model pasture growth.

2.6 Pasture growth modelling

The year to year variation in pasture yields in any location in New Zealand is a result of uncertain weather patterns and any model to be used for modelling pasture growth should incorporate crop-weather relationships. Such a model is simply any equation containing climatic factors as an input and crop production as an output (McPherson *et al.*, 1979). Crop weather models can separate environmental effects from other effects (McPherson *et al.*, 1979) and can be used to assess probabilities of yield due to variability in weather. Several papers report of attempts to model pasture growth in New Zealand (Baars *et al.*, 1987; Larcombe 1989; Baars *et al.*, 1990, Butler *et al.*,1990). Baars *et al.* (1990), discuss deficiencies of some of these models in predicting pasture growth under different management conditions, pasture species with varying growth patterns for sites and soil fertility levels. The choice of a model to represent some degree of accuracy depends on its previous applications and on how best it could represent the climatic situation of the country.

2.6.1 "GROW" model

The 'GROW' model was designed to reproduce seasonal pasture growth patterns (Butler *et al.*, 1990) obtained from cutting trials conducted by the Ministry of Agriculture and Fisheries (MAF) throughout New Zealand, reported in a series of articles in the New Zealand Journal of Experimental Agriculture from 1974 to 1987 (Gray *et al.*, 1987). The model multiplicatively combines (McPherson et al. 1979) the effect of temperature, soil moisture, soil fertility and other factors, in order to calculate predicted pasture growth (Butler *et al.*, 1990). Butler *et al.*

(1990), used the 'GROW' model to predict future changes in pasture growth rate (PGR) and annual herbage production (AHP) in New Zealand arising from the so-called green house effect. Their validation of the model for two sites, Masterton and Taieri Plains where pasture growth rates has been measured (Radcliffe, 1975a; Round-Turner *et al.*, 1976) show predicted values very close to actual measurements (Butler *et al.*, 1990). In another study Hodgson *et al.* (1992) used the 'GROW' model to predict feed supplies in pastoral livestock systems caused by environmental changes accompanying global warming. The 'GROW' model could be successfully used to predict variability in pasture yields due to weather by holding all other variables constant and changing only weather parameters.

2.6.2 Pasture based desk top dairy farm models

The 'Udder' desk top dairy management package was developed by Larcombe (1989) to predict the likely outcome of a change in management or pasture growth and the validation of the model is described in detail. Since then 'Udder' has had several revisions. Da Silva (1992) used 'Udder' to simulate late control grazing management in pasture growth studies. The output from 'Udder' model provides a comprehensive range of farm details which include pasture consumption, pasture allowance and pasture mass. In particular, 'Udder' has a feed back loop whereby animal intake is modified by pasture herbage mass. Since bST response is intake related this feature makes 'Udder' especially suitable for the purpose of modelling bST responses, as compared to other models such as 'Farmtracker' where animal intake is specified by the operator, and not modified by pasture mass.

2.7 Review of economic studies on bST

Most studies reporting on the economics of bST use are for the US dairy industry. Kalter *et al.* (1984) was among the first to make a comprehensive feasibility study of bST in the US. Based on the known characteristics of available information on bST they estimated the profitability of bST in representative farms in New York.

Fallert *et al.* (1987) used a series of econometric simulation models to assess the macro and micro impacts of bST under four policy scenarios in the US. The farm level model was of a series of linked simulation models to represent farm types based on region, farm size based on cow numbers, productivity in terms of yield per cow and financial health in terms of debt/asset ratio. The adoption rates used were based on literature review. They concluded that bST use could prove profitable for almost all dairy farms but the less efficient ones may not reap the full benefit.

Richardson (1991) used a Monte Carlo simulation model to analyze the effect of three policy scenarios for US for a ten year period. Results for the representative dairy farms show that bST adopters enjoy a greater average annual net income than non-adopters.

All of the above simulation studies use the assumption that farmers have the incentive to adopt and used different adoption levels for the periods being considered. The other important criteria varying from the present study is the use of concentrate feeds as is the practice in the US.

Zeddies and Dolushitz (FRG, 1989), Trelawny and Stonehouse (Canada, 1989) Geisen *et al.* (Netherlands, 1989) employed a linear programming approach to analyze the effect of bST in the respective countries where milk supply quotas are imposed on farm output. They share a common conclusion that farm income increases are not possible under strict quota systems. More opportunities existed for farms that had alternate uses for resources because bST needs fewer cows to fill the existing quota.

Larson and Kuchler (1990) took a different approach to previous studies to suggest a conceptual model to analyze the farm level incentives to adopt bST. Because earlier simulation studies assumed that farmers had the incentive to adopt bST, they argued that a conceptual model is required to analyze those assumptions used. Larson and Kuchler developed a short-run model to investigate the incentives available for farmers to adopt bST. The cost function developed by them does not consider the energy function to be homothetic so the mix of inputs can change.

As pointed out by Larson and Kuchler, Marion and Wills (1990) also suggested that Fallert's simulation models were sensitive to the assumptions used including the assumption on the return required by farmers to adopt the technology. Marion and Wills (1990) used a farm enterprise model to find the economic feasibility of bST adoption by farmers by comparing incremental revenues and incremental costs. They also suggest a sensitivity analysis for the variables used. Shoeffling *et al.* (1991) adopted a similar method used by Marion and Wills.

Chapter 3

MATERIALS

3.1 Introduction

The preceding review sought to establish the relationship between pasture availability and likely response of cows to bST within a seasonal framework of grassland farming in New Zealand. Evidence gathered from bST trials under intensive feeding and management systems elsewhere suggest that there are economic benefits in adopting bST technology to dairying. The vast amount of knowledge gathered on the use of bST builds up a theoretical base for a dairy management system entirely different from the New Zealand grazed pasture system. Limited work has been reported on the effect of bST in a system of grazed management but results suggest that use of bST can be accommodated provided pasture is not a limiting factor for an appropriate response. As reviewed in Chapter 2, a few studies have been conducted on bST treated cows fed on pasture which provide base information to the nature of response to bST.

3.2 Source of data

In order to determine bST responses this study uses data from a single lactation bST trial reported by Hoogendoorn *et al.* (1990). A thorough literature search failed to reveal any other long term trial on cows gazed on pasture for at least one lactation period that could provide supporting data for this study. It must be acknowledged, therefore, that there is only a limited amount of detailed information on bST use in pasture based dairy management systems.

Hoogendoorn *et al.* conducted their bST trial on cows grazed on pasture at Massey University's No.4 dairy farm in 1987/88, over a duration of one lactation cycle commencing peak lactation. They recorded the pasture mass prior to cows being sent into graze and the milkfat response to bST treatment. The measurements of pasture mass and milkfat production (Kg/cow/day) is given below:

Stage of lactation(wk)	Pasture mass (Kg/DM/ha)	Milkfat (Kg/cow/day)		
		control	bST Treated	Difference
1	2857	0.86	1.00	0.14
3	2600	0.79	0.93	0.14
5	2400	0.69	0.74	0.10
7	2543	0.68	0.77	0.09
9	-	-	-	-
11	2200	0.66	0.74	0.08
13	2400	0.52	0.54	0.02
15	1886	0.43	0.45	0.02
17	1914	0.56	0.56	0.00
19	2371	0.57	0.61	0.04
21	2514	0.55	0.62	0.07
23	2485	0.55	0.58	0.03
25	1914	0.39	0.49	0.10

Table 1. Bi-weekly pasture mass measurements and milkfat production with and without bST from Hoogendoorn *et al.* (1990).

The data used in this study was not published by Hoogendoorn *et al.* (1990) in their original manuscript and was obtained from the authors at the Department of Animal Science, Massey University.

3.3 Observations on data

The data from Hoodendoorn *et al.* relate pasture mass to milkfat output (per cow per day). The ideal situation is to relate response to bST to pasture allowance (kg DM/cow/day), the amount allocated to each cow to obtain a given response. However, Korte *et al.* (1987) are of the view that for a particular pasture combination and time of the year, pasture mass is a useful guide to expected stock performance. In view of the limited research on bST in pastoral systems, data from Hoogendoorn's trial should not be a constraint for an ex ante analysis considering the importance and the relevancy of the subject to dairying in New Zealand.

Pasture mass is not the best parameter to use in this study though a pasture allowance relationship is preferred . However, because of the nature of data there is no alternative but to use pasture mass as the key to simulating the response to bST in the pasture based dairy management system in New Zealand. On this basis the methodology selected to estimate returns to bST needs to relate pasture mass to milkfat output in a situation with and without bST use.

Chapter 4

METHODOLOGY AND ASSUMPTIONS

4.1 Introduction

Chapter 3 presented the nature of the data available for analysis. The bST trial conducted by Hoogendoorn *et al*. (1990) establishes a relationship of pasture mass to milkfat output in lactating cows administered with bST. It is clear that sufficient pasture must be available to achieve milk production efficiencies using bST. In addition literature (Section 2.3.2.2) supports this view that cows injected with bST increase voluntary intake of pasture to produce the extra milk. Arising from this is a situation where likely response to bST in New Zealand dairy farms is influenced by the availability of sufficient pasture to meet nutritional requirements of bST use

Dairying in New Zealand is concentrated in areas favourable for continuous pasture growth. Though limitations exist for short periods, generally pasture is adequate to maintain the herds in established dairying regions. Therefore some response could be expected at least during flush periods but the degree of response needs to be determined.

4.2 General approach

The impact of bST on New Zealand dairy farms is more likely to have a regional influence than of a general impact on farms across the country because of the climatic and seasonal variation influencing PGR. In this context a general approach to the problem is to relate pasture supply at different locations to findings from the trial by Hoogendoorn *et al.* (1990). However, the suggested procedure requires several steps and the next section will provide a framework for estimating the returns to bST use in New Zealand dairy farms.

4.2.1 Flow chart

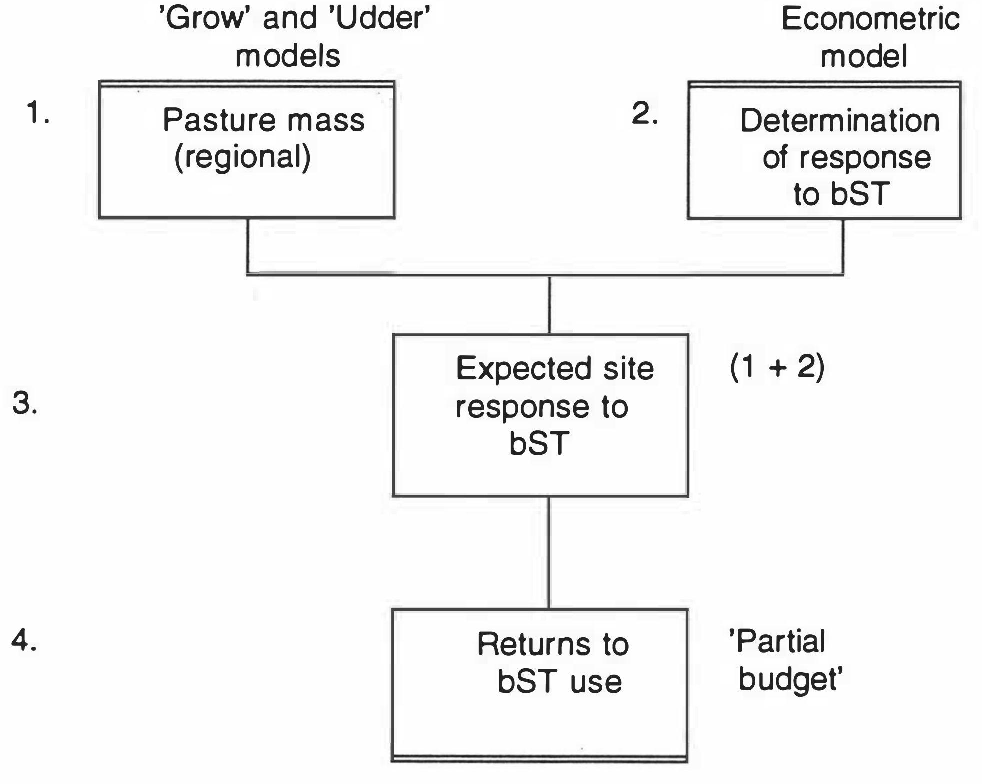

Fig.1 Flow chart for bST response estimation and calculation of returns to bST use.

4.2.2 Components of methodology

The main components of the methodology to be adopted in the study as shown by figure 1 are:

1. Estimation of average pasture mass for different times of year for selected sites.

2. Specification of an econometric model using data from Hoogendoorn's trial to extrapolate response to bST.

3. Prediction of response to bST in selected sites using pasture mass with output from econometric model.

4. Estimating returns to bST adoption in selected sites using partial budgeting techniques.

4.3 Methodology in detail

The analytical methodology underlying this study is complex due to the nature of the dairy industry in New Zealand. Two basic components were linked to simulate expected response from bST use in different sites. The first component is the simulation of pasture mass using known models followed by use of an econometric model to evaluate the response to bST. The linkage between the two components is critical to simulate site effects for different dairy regions of the country.

4.3.1 Estimation of pasture mass

Pasture mass is the term used to describe the amount of above ground parts of pasture plants expressed in terms of kg DM/ha. Pasture mass is dependent on a number of factors, including PGR, stocking rate and other management factors. PGR in turn varies with the location and climate. Literature refers to variation in pasture growth in different sites in New Zealand indicating that there is a strong likelihood that response to bST will also follow the same pattern because of the nutritional factor. Therefore it is appropriate to direct the study to selected sites.

4.3.1.1 Selection of sites

Twelve sites were selected for the study to represent popular dairying regions of New Zealand. The sites were selected after interviews with individuals involved in pasture and dairy management. The basis used here is not sufficient to explain variability within a dairying region but nevertheless describes an average situation for the region being considered. The sites selected are:

Dairying region	Site selected
North of Auckland	Warkworth
Waikato	Hamilton
Bay of Plenty	Te Puke
Central Taranaki	Stratford
South Taranaki	Manaia

Rangitikei	Wanganui
Manawatu	Palmerston North
Wairarapa	Masterton
Cantebury (North)	Winchmore
Otago	Invermay
Southland	Gore
Westland	Greymouth

4.3.1.2 Pasture growth rates for selected sites

As a first step towards estimation of pasture mass for a particular site is dependent on PGR for that site, expressed in terms of kg DM/ha/day were examined. PGRs have been reported for twenty lowland sites in New Zealand using pasture cutting methods in a ryegrass/white clover sward suggested by Radcliffe (1974a). However, these pasture cutting trials provide average PGRs for four of selected sites in the study - Stratford, Masterton, Winchmore and Invermay. PGRs for Palmerston North was obtained from records maintained for No.4 Dairy farm of Massey University. PGR for the remaining sites were simulated using the 'GROW' model, a pasture growth rate predicting model that has had previous applications in different studies in New Zealand (Section 2.6.1).

The 'GROW' model requires input of several variables - monthly mean temperature, monthly mean rainfall (mm), pasture species, soil texture, monthly mean evapotranspiration (mm), management type, geographical location and fertility level of the soil. To be consistent with other published PGRs the input of pasture species to the grow model was assumed to be ryegrass/white clover swards on a 28 day management rotation. Long term mean monthly temperatures, rainfall and evapotranspiration data was collected from publications of the New Zealand meteorological Service (1986). Other input used to simulate PGR for the sites using the 'GROW' model is given in appendix 3.

4.3.1.3 Simulation of pasture mass

The 'Udder' desk top dairy farm package - version 7.0, was used to simulate pasture mass for different periods in a year for the sites selected. Average regional farm characteristics such as farm size, stocking rates (NZ, Dairy Board, 1994) and PGR from the preceding section were the primary inputs to run the model. The assumptions used to simulate 'Udder' is given in appendix 4.

4.3.2 Specification of an Econometric model to predict response rates

An econometric model was specified for the main source of data presented in Chapter 3, using milkfat as the dependent variable and pasture mass as the explanatory variable. Two explanatory variables were defined (x_1, x_2) for pasture mass; x_1 for the control group and x_2 to test the treatment effect of bST on pasture mass. The set of data provide measurements for eleven uniform periods in different stages of lactation. Ten dummy variables ($D_1,...,D_{10}$) were used to generate the lactation stage effect for the eleven biweekly periods in the trial. An additional dummy (T) was specified to test the differences in intercept between the treated and control groups. To avoid specification errors in the model where the number of variables exceed the number of observations in the data set, the number of observations were doubled from 11 to 22 using the two sets of data from the control and treated groups. The basic model takes the form:

$$\mathbf{Y = f(X_1, X_2, D_1, \ldots D_{10}, T)}$$

where, Y = milkfat (kg/cow/day)

X_1 = pasture mass (control and treated groups)

X_2 = pasture mass (control group = 0; to test differences in slope)

D_i = dummy variable for stage of lactation (i = 1 to 10)

T = dummy variable to test difference in intercept (treated = 1)

Assumptions: The model tests for 1) difference in slope

2) difference in intercept between control and treated groups.

The Minitab statistical package was used for the regression analysis.

4.3.3 Prediction of response to bST in selected sites

A spread sheet was developed on Quattro Pro to link the bST response function to pasture mass data simulated by the 'Udder' model for the twelve selected sites. Likely milkfat responses to bST use in the different stages of lactation was obtained for calculation of returns.

4.3.4 Farm level returns to bST adoption

BST is a technology requiring changes in operating costs and involves no commitment on the capital structure of the farm enterprise (Fallert *et al.*, 1987). Adopting the technology makes small changes to the structure of the farm operation. Partial budgeting is a method of estimating the likely effect that changes in policy in part of the business as in adopting bST may have on the future profitability of the farm business. It is one method to test the financial implications of proposed improvements and alterations (Norman *et al.*, 1985). Thus partial budgeting is appropriate to determine the returns to bST on dairy farms. This study follows the farm enterprise model suggested by Marion and Wills (1990) to compare incremental revenues and incremental costs. The model is described below:

Incremental returns to bST = Incremental milkfat production with bST per cow * milk price.

Incremental costs plus return to management. = Cost of bST + Extra labour costs + Other variable costs + required return to management.

The required return to management measures the threshold returns to farmers who adopt bST as a payment for management.

Partial budgets were prepared to estimate the returns for the sites selected earlier in this Chapter followed by a sensitivity analysis using parameters of cost of bST, returns to management and price of milk.

4.4 Assumptions

Several assumptions were made to cover the areas still not being answered about the use of bST. The **major assumption** is on the response to bST in grazed management. Actual response to bST will vary from farm to farm according to climate, pasture growth rates and other farm characteristics but there are no data that quantify this variability. Thus the study assumes that response to bST in New Zealand is in accordance to the response observed in Hoogendoorn's trial (1990) described in Chapter 3. Milk production increases observed in the trial by Hoogendoorn *et al.* (1990) were with existing pasture resources and with no changes in stocking rates. As this study is dependent on the results obtained from their bST trial, this study will assume likely increases in milk production using bST with available farm resources and with no changes in stocking rate. The other assumptions of the study are summarised here.

Cost of bST: A pharmaceutical company indicates that the cost of a dose of sustained release formulation will cost approximately $NZ 8.00 to 9.00 (NZ 64c/US 1.00 exchange rate). The cost of bST is assumed at $NZ 8.00 in this study.

Feed use: The study assumes that farmers will adjust feeding to meet the additional pasture requirements of bST use. It is assumed that treated cows will consume 5 percent more pasture that will be partitioned for extra milk production.

bST treatment: Study assumes five monthly sustained release formulations are administered during the lactation cycle, beginning 10 weeks post partum. The genetic merit of the cow is assumed average. Literature indicates that cows of low genetic merit respond best to bST treatment in pasture based dairying (Chapter 2). The assumption of average genetic merit is appropriate as New Zealand farms carry animals of improved genetic merit. Study also assumes that the technology is scale neutral.

Labour: The amount of additional labour required for the injection and the increased milking times at the higher production levels has not been quantified. The study by Fallert *et al.* (1987) assume an extra labour requirement of 0.32 mandays per cow. However since no extra labour is required for feeding in pasture based dairy management systems this study will assume 0.20 mandays (1.6 hours) of extra labour per animal for the bST treatment period.

Price of milkfat: The 1992/93 average dairy company payouts per kilogram milksolids = $ 3.66 equivalent to $ 6.40 per kilogram milkfat. This study assumes a base price of $ 6.50 per kilogram of milk fat.

Other assumptions: Numerous studies have established that bST has no adverse effect on health of cattle and humans. Many scientific and medical organizations endorsed this. The study will assume that long term animal health and reproduction effects are minimal. Consumer acceptance of milk produced with bST is not affected.

4.4.1 Limitations of the major assumptions

Several of the assumptions are open to question. Though an equal response is assumed, the actual response to bST could vary with different pasture species and climate in New Zealand. The conclusion drawn from a single trial is limited in predicting bST's effects on varying actual farm conditions. However, this analysis assumes that all representative farm categories will respond similarly in terms of yield response to bST.

It is not known whether farmers use optimum stocking rates in New Zealand. Whether these farmers will adjust production practices particularly feeding through adjustment of stocking rate and animal health to new production levels is unknown. If farmers fail to make the necessary adjustments it may result in not achieving any response to bST.

Numerous studies have noted that milk from bST treated cows may be rejected by consumers even if approved by scientific and medical groups (McGuirk *et al*., 1992; Preston *et al*., 1991; Kaiser *et al*.,1992) . Though milk from treated cows is being sold in the US market it is still not known conclusively how the market operates for this milk. It is difficult to measure consumer reactions ex ante. Many have also predicted low prices for milk produced using bST (Kaiser, 1992; Shoeffling *et al*.,1991).

Chapter 5

RESULTS AND DISCUSSION

5.1 Introduction

Literature refers to feed supply as the primary factor for increased milk response to bST in cows (Bauman, 1992). Limited bST trials on grazed pasture confirm that sufficient quantities of pasture must be available to achieve any response to bST. New Zealand's unique pasture based dairy management system makes good use of the available pasture with little or no supplementary feeding. In this uniquely managed dairy system any response to bST will take place only if extra energy is available for the cow to perform appropriately. Climatic variation due to this seasonal nature and the geographical spread of the dairy industry in New Zealand does influence pasture growth and availability of pasture to the cow in order for there to be a response to bST. The twelve sites selected from different dairying regions in New Zealand were to examine likely regional and year to year variation in response to bST. The year to year differences in pasture growth within a site has been reported (Radcliffe and Baars, 1986). This fluctuation is a result of changing weather patterns and is accounted for in the study by using long term average PGR. As discussed earlier (Chapter 3) this study relies on pasture mass data to simulate response to bST and in order to predict pasture mass it is necessary initially to obtain PGR for the selected sites. Subsequent simulation of pasture mass data may then be used as a basis for calculating the response to bST, and finally the financial returns to its use at the given locations. Section 5.1 will deal with pasture growth rates and pasture mass data for the selected locations. Section 5.2 will establish the response function to bST while section 5.3 will look into the expected response to bST at these locations. The final Section (5.4) explores the financial implications of bST and provides an indication of the incentive for adoption of the hormone by dairy farmers in New Zealand.

5.2 Pasture Growth Rates (PGR) and pasture mass data for the selected sites

5.2.1 Pasture growth rates for the selected locations

PGR measurements have been reported for 20 sites in New Zealand published as a series of articles in the New Zealand Journal of Experimental Agriculture. However, only six of these measurements are relevant to sites selected in this study. For the balance seven sites where pasture growth information is not available the 'GROW' model was used to simulate pasture growth rates using long term weather data for these locations as the required model input. Prior to the simulation process the 'GROW' model was validated against measured pasture growth data for Massey University's no. 4 dairy farm for 1987/88. This is the same site where Hoogendoorn *et al.* (1990) conducted the bST trial on cows managed on grazed pasture. The validation of the model (Table 2) shows that 'GROW' is accurate enough to be used for prediction of PGR for those sites where information was not available. A discrepancy was observed in the validation for the month of September where the measured PGR was 68 kg dm/ha/day and the predicted PGR was 58 kg dm/ha/day. It is the view of pasture agronomists at Massey that it is usual to experience increased pasture growth following periods of low temperature. Davies (1994) also referred to a cold-induced growth enhancement of pasture in describing differences in seasonal growth between Wales and Palmerston North. This effect of temperature can also be seen in seasonal growth curves for perennial ryegrass presented by Mitchell (1956b). Since the winter in question was colder than normal, such a response would be expected in the measured data, but not predicted by the simulation. This phenomena is not taken into account by the 'GROW' model. Table 3 gives the simulated pasture growth obtained by using the 'GROW' model for sites where measured pasture growth data were not available. Appendix 3b provides the climate and other data used to predict long-term average PGR at relevant sites.

Massey no. 4 farm	Ju	A	S	O	N	D	J	F	M	A	M	J
Measured	18	44	68	53	37	28	13	39	25	32	30	29
Simulated	19	44	58	52	40	29	12	39	24	31	31	26

Table 2. Validation of PGR (kgDM/ha/day) using 'GROW' model for Massey University's no.4 dairy farm - 1987/88.

5.2.2 Simulation of pasture mass data for selected sites using the 'Udder' model

As discussed in Chapter 3, because of the nature of the data available for analysis, pasture mass will be the basis for calculating likely response to bST at any location. Pasture mass data is normally not readily available as a measurement in pasture studies and had to be simulated using an appropriate model. The 'Udder' model was used for this purpose as its output provides pasture mass data for a given farm situation. To validate herbage mass data obtained from the 'Udder' model, model output for a simulation of the trial by Hoogendoorn *et al.* (1990) at Massey University,s No. 4 dairy farm was compared with actual herbage mass collected during the trial. PGR data used to validate the 'Udder' model was the measured data given in Table 2. Results of this validation of the 'Udder' model are given in table 5. Allowing for differences in pasture mass measurement intervals in the trial and the 'Udder' simulation output, the results closely follow the trend of measured data. Further details of the simulated 'Udder' output on pasture measurements for Massey University's no. 4 dairy farm for the trial period are given in appendix 6.

Month	Wakworth	Te Puke	Hamilton	Manaia	Wanganui	Gore	Greymout
July	23	21	20	12	10	4	10
Aug.	30	37	35	15	22	9	14
Sept.	37	55	53	29	42	21	21
Oct.	56	60	56	52	52	49	28
Nov.	59	61	53	60	40	55	47
Dec.	59	52	50	54	42	59	45
Jan.	42	40	34	45	32	52	47
Feb.	35	32	33	40	28	46	41
March	46	38	40	35	27	41	34
April	47	40	32	32	30	27	26
May	36	34	28	26	24	15	16
June	24	22	18	17	16	5	12

Table 3. Pasture growth rates (kg DM/ha/day) simulated using the 'GROW' model. Long term average weather data for the selected sites were used as the basis for the simulation.

Month	Stratford	Palmerston North	Masterton	Winchmore	Winchmore -Irrig.	Invermay
July	7	17	15	5	5	5
August	10	27	28	14	9	10
Sept.	21	39	42	28	24	28
Oct.	40	50	66	41	41	45
Nov.	60	46	51	31	38	53
Dec.	57	37	30	19	47	47
Jan.	52	25	16	13	48	24
Feb.	47	23	10	13	45	33
March	35	21	23	16	35	33
April	36	23	19	16	23	22
May	32	29	28	8	8	8
June	23	22	16	5	5	5
Source	Roberts et al 1984	Massey Univ. records	Radcliffe 1975	Richard et al 1976	Richard et al 1976	Round-Turner et al 1976

Table 4. Published pasture growth rate data for sites selected for the study. Simulations were not performed where measured data was available. Data in tables 3 and 4 were used to simulate pasture mass.

To compare pasture mass actually observed by Hoogendoorn *et al.* (1990) with that predicted by 'Udder', Fourier series curves were generated to describe the time-course of herbage mass. The method used was that described by Lambert *et al.* (1986). To apply the Fourier series to the period of the trial by Hoogendoorn *et al.* (1990) the time measurements of the trial was scaled to 360 degrees.

Month	Monthly pasture growth rates kgDM/ha/day	Pasture mass measurements from trial kgDM/ha	Pasture mass results from 'Udder' model kgDM/ha	dates of 'Udder' measurements
Oct.	53	-	-	-
		-	-	-
		2857	2878	21.10
Nov.	37	2600	2660	01.11
			2660	11.11
		2400	2393	21.11
Dec.	28	2543	2410	01.12
			2510	11.12
		-	2449	21.12
Jan.	13	2200	2511	01.01
			2254	11.01
		2400	2091	21.10
Feb.	39	1886	2057	01.02
			2180	11.02
		1914	2360	21.02
March	25	2371	2520	01.03
			2580	11.03
		2514	2106	21.03
April	32	2485	1800	01.04
			2107	11.04
		1914	2360	21.04

Table 5. Validation of 'Udder' model for simulation of herbage mass. Columns 3 and 4 show respectively, conditions that prevailed in No. 4 Dairy farm (1987/88) and values predicted by Udder during the trial period of Hoogendoorn et al (1990).

$$Y = a \sin x + b \cos x + c \sin 2x + d \cos 2x$$

Where, a, b, c and d are coefficients

x is the day of the lactation cycle

Y is herbage accumulation

Regression coefficients for Fourier equations describing the course of herbage mass are given in table 6.

Predictor	Coefficients (+/- s.e) of Fourier equation describing time course of herbage mass.	
	Udder prediction	Measured data
Constant	2439.76 (28.17)	2413.98 (55.90)
sin	176.65 (36.37)	241.84 (72.18)
cos	245.35 (42.44)	228.14 (84.24)
sin 2x	-0.80 (38.52)	-16.47 (76.44)
cos 2x	121.43 (40.96)	188.88 (81.33)
R-sq.	93%	82.6%

Table 6. Regression coefficients from Fourier series for predicted and measured pasture mass data for Massey University,s No. 4 Dairy farm.

Since in a Fourier curve the varying sine and cos terms sum to zero, the constant is the average herbage mass over the time it explains. The actual and predicted were remarkably similar being 2413 and 2439 kg dm/ha respectively. Further more none of the sine or cos terms varied significantly. The largest deviation noted was 150 kg dm/ha. It is seen from this that the 'Udder' model is suitable for prediction of pasture mass for the selected sites.

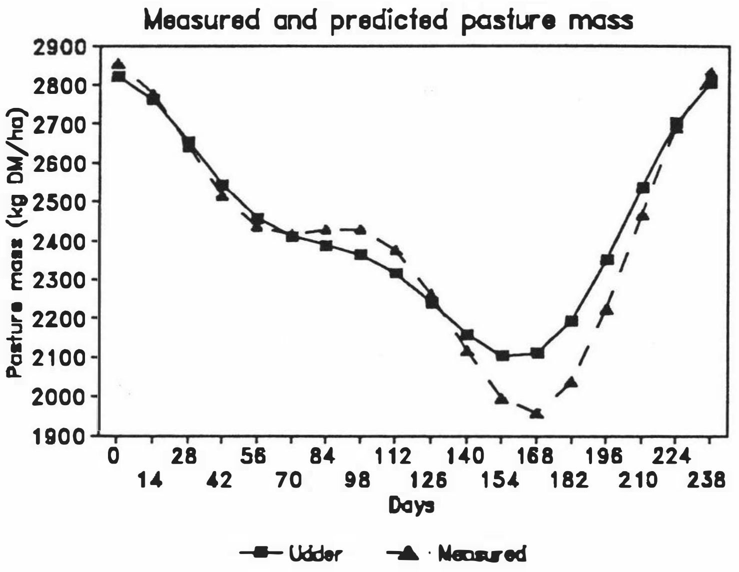

Fig 2. Comparison of Fourier curves derived for predicted and measured pasture mass for Massey University's No. 4 dairy farm (1987/88).

Using pasture growth rate data from tables 3 and tables 4 and using average regional farm characteristics, the 'Udder' model was used to simulate pasture mass data for the 12 selected sites for the 150 day bST treatment period commencing peak lactation. Tables 7 and 8 provide the results of simulated pasture mass data from the 'Udder' model with average farm characteristics of herd size and effective hectares (appendix 4).

Date	Pasture Mass (kgDM/ha)							
	Wakworth	Te Puke	Hamilton	Stratford	Manaia	Wanganui	Palmerston N	Masterton
21.10	3081	2943	2984	2045	2532	2722	2479	2830
01.11	3306	2748	3037	2238	2632	2720	2772	2788
11.11	3255	2682	2866	2246	2743	2655	2845	2688
21.11	3399	2328	2837	2457	2991	2630	2723	2805
01.12	3424	2597	2712	2545	3150	2532	2740	2684
11.12	3529	2617	2630	2539	2991	2496	2571	2615
21.12	3538	2714	2422	2819	2985	2371	2480	2373
01.01	3434	2775	2154	2676	2887	2218	2153	2150
11.01	3369	2871	2295	2818	2895	2402	2261	2082
21.01	3313	2770	2027	2663	2522	2166	1962	1878
01.02	3432	2802	2146	2720	2752	2272	2066	1859
11.02	3410	2670	2020	2520	2589	2120	2044	1888
21.02	3525	2687	2111	2566	2719	1989	2083	1896
01.03	3615	2612	2079	2538	2627	1967	2094	1950
11.03	3555	2657	2160	2611	2677	2160	2130	2076
21.03	3683	2695	2240	2459	2665	2180	2145	1881

Table 7. Pasture mass data simulated by 'Udder' model for North Island sites using average regional farm size and stocking rates with average pasture growth rates for respective sites.

Date	Pasture mass kgDM/ha				
	Winchmore	winchmore-Irrigated	Invermay	Gore	Greymouth
21.10	2090	1999	2164	1918	1686
01.11	2041	2030	2260	1891	1717
11.11	2078	2062	2330	1946	1826
21.11	2010	1882	2456	2114	1963
01.12	1958	1821	2537	2267	2109
11.12	1849	1913	2617	2471	2245
21.12	1801	1913	2621	2681	2392
01.01	1729	2036	2571	2920	2600
11.01	1740	2121	2534	3127	2781
21.01	1715	2279	2416	3374	2713
01.02	1771	2488	2402	3582	2801
11.02	1837	2716	2368	3562	2769
21.02	1909	2601	2411	3657	2800
01.03	1969	2678	2413	3634	2753
11.03	1935	2578	2469	3719	2757
21.03	1928	2452	2632	3709	2696

Table 8. Pasture mass data simulated by 'Udder' model for South Island sites using average farm size and stocking rates with average pasture growth rates for respective sites.

5.3 Econometric model for bST response function

The econometric model specified in Chapter 4 (model 1) was used to obtain the response to bST in pasture based systems of dairying. The parameters were estimated for the measured milk response data from the trial of Hoogendoorn *et al* (1990) given in Chapter 3.

5.3.1 Model 1 $Y = f(X_1, X_2, D_1, \ldots D_{10}, T)$

refer Chapter 4 for definition of variables.

Table 9 gives the predicted parameters by running a regression on model 1 using the statistical software Minitab.

Predictor	Co-efficient	t-ratio	Prob.
Constant	-1.03300	-0.49	0.633
X_1	0.00627	0.75	0.472
X_2	0.00012	3.32	0.009
d_1	0.10840	0.36	0.725
d_2	0.21569	2.49	0.034
d_3	0.23362	2.73	0.023
d_4	0.12000	2.86	0.019
d_5	0.33160	1.32	0.219
d_6	0.02362	0.28	0.789
d_7	0.28810	0.56	0.588
d_8	0.38880	0.79	0.443
d_9	0.10360	0.95	0.368
T	-0.23091	-2.56	0.031

R-sq = 98.9% R-sq (adj) = 97.4%

Table 9. Parameter estimates from econometric model 1

The variable d_{10} was removed from the equation by the software because d_{10} was very highly correlated with other X variables.

The **co-efficient of determination** (R-sq) is 98.9%. R-sq explains the proportion of total variation in the dependent variable (Y = milkfat) explained by fitting the regression. R-sq. is an index of how well Y can be explained by all the regressors i.e, how well a multiple regression fits the data (Wannacott and Wannacott, 1979).

$$R\text{-}sq = \frac{\Sigma\,(\hat{Y}_i - \bar{Y})^2}{\Sigma\,(Y_i - \bar{Y})^2}$$

$$= \frac{\textit{Variation of Y explained by the regression}}{\textit{Total variation of Y}}$$

A very high R-sq. of 98.9% for the econometric model 1 indicates that 98.9% of the total variation in milkfat production is represented by the explanatory variables used in the model.

The explanatory variable ($X_2 = \beta X$)[1] used to test the difference in slope from the control ($X_1 = \delta X$)[2] is significant at 0.9%. Thus the treatment effect is significantly different from the control. The intercept of the bST treated group (T)

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is also significantly different at 3% from the control (α_0). However, for some periods the stage of lactation effect were non-significant (d_1, d_5, d_6, d_7, d_8, d_9).

5.3.1.1 Analysis of variance - model 1

An analysis of variance performed for model 1 is presented in table 10.

Source	DF	SS	MS	F	Prob.
Model 1	12	0.470380	0.392000	66.82	0.000
Error	9	0.005279	0.000587		
Total	21	0.475677			

Table 10. Analysis of variance for econometric model 1.

The model is highly significant at F = 66.82 > P 0.000. The explanatory variables as a group provides a significant explanation of the dependent variable milkfat (Y). Where F ratio is,

$$F = \frac{\hat{\beta}^2 . \sum x_i^2}{s^2}$$

$$= \frac{\textit{Variance explained by regression}}{\textit{Unexplained variance}}$$

Since the effects of some of the stage of lactation dummy variables (d_1, d_5, d_6, d_7, d_8, d_9) were non-significant a second model excluding them was tested.

5.3.2 Model II $Y = f(X_1, X_2, d_2, d_3, d_4, T)$

The results of the regression model II is presented in table 11.

Predictor	Co-ef.	t-ratio	Prob.
Constant	-0.023200	-0.08	0.934
X1	0.000260	2.24	0.040
X2	0.000125	0.79	0.443
d_2	0.15987	2.00	0.064
d_3	0.10439	1.36	0.194
d_4	0.04326	0.55	0.590
T	-0.2309	-0.61	0.553

R-sq = 67.2% R-sq (adj) = 54.1%

Table 11. Parameter estimates from econometric model II

The co-efficient of determination (R-sq) declined from 98.9% in model 1 to 67.2% in model II. The analysis of variance done to test the appropriateness of model II in explaining the variation in milkfat by use of bST is given in table 12.

Source	DF	SS	MS	F-ratio	Prob.
Model II	6	0.31958	0.05326	5.12	0.005
Error	15	0.15609	0.01041		
Total	21	0.47568			

Table 12. Analysis of variance for econometric model II

In model II the explanatory variables as a group is significant at F = 5.12 > P 0.005 (table 12) in providing an explanation in the variation of Y. However, the probability levels declined from model 1. The error mean square increased from 0.000587 in model 1 to 0.01041 in model 2. Thus model 1 is superior to model II in explaining the variation in milkfat (Y). The stage of lactation effects though nonsignificant in model 1 needs to be included for a better fit of data.

The regression equation from model 1 is,

$$\mathbf{Y = -1.033 + 0.000627\ X_1 + 0.000125\ X_2 + 0.108\ d_1 + 0.216\ d_2 + 0.234\ d_3 + 0.120\ d_4 + 0.332\ d_5 + 0.0236\ d_6 + 0.288\ d_7 + 0.389\ d_8 + 0.104\ d_9 - 0.231\ T}$$

With adjustments for differences in intercept and slope of the regression line between the bST treated and control groups the final equation will take the form,

Model equation for control group:

$$Y = \alpha_0 + \beta X + \eta D_l$$

$$Y = -1.033 + 0.006272\ X + 0.108\ d_1 + 0.216\ d_2 + 0.234\ d_3 + 0.120\ d_4 + 0.332\ d_5 + 0.0236\ d_6 + 0.288\ d_7 + 0.389\ d_8 + 0.104\ d_9$$

Model equation for bST treated group:

$$Y = \alpha_0 + \beta X + T + \delta X + \eta D_l \qquad (1)$$

$$Y = (\alpha_0 + T) + (\beta + \delta) X + \eta D_l \qquad (2)$$

where, β = co-efficient of X_1

δ = coefficient of X_2

η = co-efficients of d_i

α_0 = intercept of control

T = difference in intercept of bST treated group

$$Y = -1.264 + 0.0007522\ X + 0.108\ d_1 + 0.216\ d_2 + 0.234\ d_3 + 0.120\ d_4 + 0.332\ d_5 + 0.0236\ d_6 + 0.288\ d_7 + 0.389\ d_8 + 0.104\ d_9$$

The fit from the model to the pasture mass measurements by Hoogendoorn *et al* (1990) in their trial is compared in table 13.

Since the pasture mass for the selected locations and for different periods is known the bST response function for grazed pasture obtained from the econometric model can be used to estimate likely response to bST.

5.4. Estimation of response to bST in selected sites

The pasture mass simulated for selected locations using the 'Udder' model in section 5.1.2 is used here with the econometric model to predict expected milkfat output with bST. However there was a practical difficulty in linking the two sets of data because of variation in their expression of time intervals. The pasture mass output from the udder model is expressed in ten day intervals whereas the econometric model output for stage of lactation is based on fourteen day periods

		bST treated		Control	
Period (wks)	Pasture mass (kgDM/ha)	Actual MF (kg)	Predicted MF (kg)	Actual MF (kg)	Predicted MF (kg)
1	2857	1.00	0.99	0.86	0.87
3	2600	0.93	0.91	0.79	0.81
5	2400	0.79	0.77	0.69	0.70
7	2543	0.77	0.77	0.68	0.68
9	*	*	*	*	*
11	2200	0.74	0.72	0.66	0.69
13	2400	0.54	0.56	0.52	0.50
15	1886	0.45	0.44	0.43	0.44
17	1914	0.56	0.56	0.56	0.56
19	2371	0.61	0.62	0.57	0.56
21	2514	0.62	0.63	0.55	0.54
23	2485	0.58	0.60	0.55	0.53
25	1914	0.49	-	0.39	-

Table 13. Actual MF response measured by Hoogendoorn *et al* (1990) against the fit from the model.

corresponding to the intervals used in the trial by Hoogendoorn *et al* (1990). A correction was required to bring the time intervals to a common basis. It was not possible to change the pasture mass output intervals specified by the 'Udder' model as it requires changes in the software. Thus the 10 day interval used by 'Udder' was kept unchanged while the stage of lactation effects obtained using dummy variables in the econometric model were weighted to match the 10 day intervals for pasture mass observations. Table 14 gives the weighted coefficients used to obtain the stage of lactation effects.

Date	Weighted d_i co-ef.s for stage of lactation effects
21.10	0.18
01.11	(0.18 * 0.4) + 0.216 * 0.6)
11.11	(0.216 * 0.8) + (0.234 * 0.2)
21.11	0.234
01.12	(0.234 * 0.2) + (0.12 * 0.8)
11.12	(0.120 * 0.6) * (0.226 * 0.4)
21.12	0.226
01.01	0.332
11.01	(0.332 * 0.4) + (0.0236 * 0.6)
21.01	(0.0236 * 0.8) + (0.288 * 0.2)
01.02	0.288
11.02	(0.288 * 0.2) + (0.389 * 0.8)
21.02	(0.389 * 0.6) + (0.104 * 0.4)
01.03	0.104
11.03	0.104
21.03	0.104

Table 14. Set of weighted co-efficients for stage of lactation effect used to predict response to bST.

The procedure still maintains the duration of 14 days for each d_i and corresponds to the total lactation length used in the trial. The weighted coefficients now correspond to the pasture mass output of 10 day intervals from the 'Udder' model. Where data was missing the mean of the coefficients of d_i's immediately prior to and post to that interval was assumed. As d_{10} was removed from the econometric model due to correlation, the bST response received in period d_9 was assumed for period d_{10}.

5.4.1 Nature of response to bST

As reviewed in Chapter 2 the nature of response to bST at very high pasture mass levels is not clear from evidence gathered from literature. It was necessary to learn the nature of the response to bST at higher levels of pasture mass prior to estimating response to bST. The point of maximum response must be known to avoid misinterpretations during extrapolation. An asymptotic response curve (diminishing response at higher levels because of intake limitations) typical of biological functions can be expected for bST at higher levels of pasture mass. To test for diminishing response a straight line model and a quadratic curve model are fitted using Statistical Analysis Software (SAS) to the data in Chapter 3 (milkfat produced per cow per day) in the bST treated group against pasture mass. The results from comparison of linear and quadratic model are presented in table 15.

Comparing results of analysis of variance for the two models (table 15), the straight line model is better in explaining the variation in production of milkfat than the quadratic model at a greater significance level of 14.64 at a probability of F > 0.0033. A straight line model shows a better fit for the range of pasture mass data from 1800 to 2800 kgDm per hectare available from the trial of Hoogendoorn *et al* (1990). However, being a biological function an indefinite linear response to bST cannot be expected at higher levels of pasture mass. Thus to avoid errors of extrapolation the maximum pasture mass is assumed at 3000 kgDM per hectare above which grass is assumed to be cut for conservation.

Source	F value	Prob > F	R-sq
Straight L Model	14.641	0.0033	0.5942
Quadratic curve model	8.257	0.0092	0.6473

Table 15. Summary of analysis of variance for straight line model and quadratic curve model

5.4.2 Response to bST in selected sites

A spreadsheet developed on Quattro Pro linked the econometric model specifying the response to bST with pasture mass data from the 'Udder' model. A summary of predicted responses for the selected sites is provided in table 16.

Detailed estimates of likely milkfat response to bST for the 12 sites is presented in Tables 17 to 28. The pattern of response expected for these sites during the lactation cycle are indicated in figures 3 to 15. The results are based on average farm size, average herd size and average pasture growth rates for the regions being considered. Since this study is based on the findings of Hoogendoorn *et al.* (1990), the pronounced feature is that an increase in milkfat with bST is related to the pasture availability at each location. Figures 3 to 15 clearly illustrate this trend. Results generated for seasonal herds in the twelve locations suggest four different trends in extra milkfat production in response to bST. The four patterns observed are based mainly on pasture supply required to meet the energy demands of the cow for an appropriate response. The patterns of response to bST are described next.

Location	Dairy Region	Annual Pasture Growth kgDM/ha	Difference in MF response (bST-control) kgmf	% response	Stocking rate cows/ha
Warkworth	North of Auckland	15685*	23.04	13.8	2.0
Te Puke	Bay of Plenty	15984*	17.00	12.5	2.5
Hamilton	Waikato	14531*	11.39	10.6	2.7
Stratford	Central Taranaki	12030	12.85	11.4	2.4
Manaia	South Taranaki	14770*	18.30	13.0	2.6
Wanganui	Rangitikei	12259*	9.71	10.0	2.25
Palmerston North	Manawatu	11820	9.81	10.0	2.25
Masterton	Wairarapa	10880	8.26	8.8	2.5
Winchmore	Canterbury	5870	1.03	1.9	2.3
-irrigated	Canterbury	10160	7.14	8.1	2.3
Invermay	Otago	10390	12.04	10.8	2.1
Gore	Southland	11261*	15.54	12.0	2.0
Greymouth	Westland	11304*	11.55	10.0	1.8

Table 16. Predicted increase in milkfat production by use of bST under average conditions in different sites in New Zealand.

* estimated

1. Continued response to bST throughout lactation: This trend is observed for Warkworth (fig. 3), Te Puke (fig. 4), Invermay (fig. 13), Manaia (fig. 7), and Stratford (fig. 6). Consistently high pasture cover during lactation provides this trend in response.

2. Milkfat response to bST prominent during mid lactation: Observed in the remaining sites of North Island not included in (1) - Palmerston North (fig.9), Wanganui (fig.8), Masterton (fig.10) and Hamilton (fig.5) follow this trend. The response to bST is restricted to the early and mid-lactation periods because of limitations to pasture growth during the dry summer months. The relatively high stocking rates being used also puts more pressure on available pasture during the dry period and further restricting the possibility of any response to bST.

3. Milkfat response to bST is prominent during latter stage of lactation: Observed in the balance sites in the South Island not included in (1). A response in the early stage of lactation is limited by low pasture growth accompanied by low pasture mass during spring which is sufficient only to meet the increased demand of peak lactation. Good pasture growth during the latter stages of lactation enables production of extra milk fat in treated cows. Gore (fig.14) and Greymouth (fig.15) follow this trend.

4. Unlikely response to bST: Low pasture growth is unfavourable for an added response to bST. The dry site in Winchmore (fig.11) follows this trend. Results generated for an irrigated site in Winchmore (fig.12) indicate a low response to bST during early to mid-lactation as common to other sites in the South Island. However irrigation of pastures during the dry summer months enable a response to bST. The irrigated site in Winchmore takes a similar trend described under category (3) above.

From this section it is clear that pasture growth controls the response to bST on cows grazed on pastures. Since the response to bST in the twelve selected locations have been estimated it must be known whether this extra

Location: Warkworth
Average herd size: 170
Average effective hectares: 83

		bST treated		Control			Percentage
Date	Pasture mass (kgDM/ha)	KgMF/cow per day	Total MF for pd.	KgMF/cow per dy	Total MF for pd.	Difference (kg/cow/d)	of total response
11.10							
21.10	3081	1.10	11.01	0.96	9.57	0.144	6.25
01.11	3306	1.17	11.65	1.02	10.21	0.144	6.25
11.11	3255	1.21	12.12	1.07	10.68	0.144	6.25
21.11	3399	1.23	12.27	1.08	10.83	0.144	6.25
01.12	3424	1.14	11.35	0.99	9.91	0.144	6.25
11.12	3529	1.16	11.55	1.01	10.11	0.144	6.25
21.12	3538	1.22	12.19	1.07	10.75	0.144	6.25
01.01	3434	1.32	13.25	1.18	11.81	0.144	6.25
11.01	3369	1.14	11.40	1.00	9.96	0.144	6.25
21.01	3313	1.07	10.69	0.93	9.25	0.144	6.25
01.02	3432	1.28	12.81	1.14	11.37	0.144	6.25
11.02	3410	1.36	13.61	1.22	12.17	0.144	6.25
21.02	3525	1.27	12.68	1.12	11.24	0.144	6.25
01.03	3615	1.10	10.97	0.95	9.53	0.144	6.25
11.03	3555	1.10	10.97	0.95	9.53	0.144	6.25
21.03	3683	1.10	10.97	0.95	9.53	0.144	6.25
01.04							
Total			189.46		166.42	2.304	100

Difference (kgMF) 23.04
% response to bST —- 13.8

Table 17. Likely response per cow to bST under average conditions in Warkworth obtained by fitting bST response function to simulated pasture mass data.

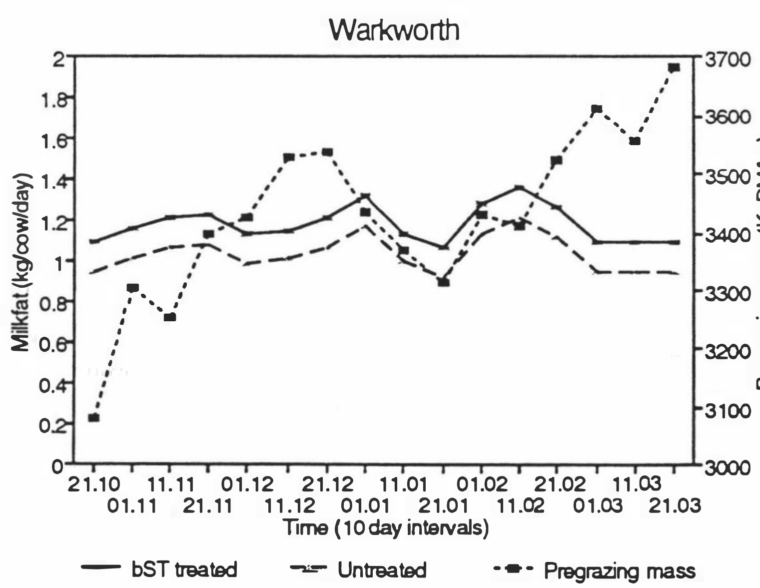

Fig.3 Comparison of expected milkfat production per cow in bST treated and control groups against average pasture mass in Warkworth.

Location: Te Puke
Average herd size: 196
Average effective hectares: 78

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per dy	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	2943	1.06	10.58	0.92	9.21	0.137	8.06
01.11	2748	0.98	9.76	0.86	8.63	0.112	6.59
11.11	2682	0.97	9.73	0.87	8.69	0.104	6.13
21.11	2328	0.72	7.21	0.66	6.61	0.06	3.54
01.12	2597	0.83	8.32	0.74	7.39	0.094	5.53
11.12	2617	0.87	8.67	0.77	7.71	0.096	5.65
21.12	2714	1.00	10.03	0.90	8.95	0.108	6.36
01.01	2775	1.16	11.55	1.04	10.39	0.116	6.83
11.01	2871	1.04	10.43	0.91	9.15	0.128	7.53
21.01	2770	0.90	8.96	0.78	7.81	0.115	6.77
01.02	2802	1.13	11.32	1.01	10.12	0.119	7
11.02	2670	1.11	11.13	1.01	10.10	0.103	6.06
21.02	2687	1.03	10.32	0.93	9.27	0.105	6.18
01.03	2612	0.80	8.05	0.71	7.09	0.095	5.59
11.03	2657	0.84	8.39	0.74	7.37	0.101	5.94
21.03	2695	0.87	8.67	0.76	7.61	0.106	6.24
01.04							
Total			153.12		136.12	1.699	100

Difference (kgMF) 17.00
% response to bST — 12.5

Table 18. Likely response per cow to bST under average conditions in Te Puke obtained by fitting bST response function to simulated pasture mass data.

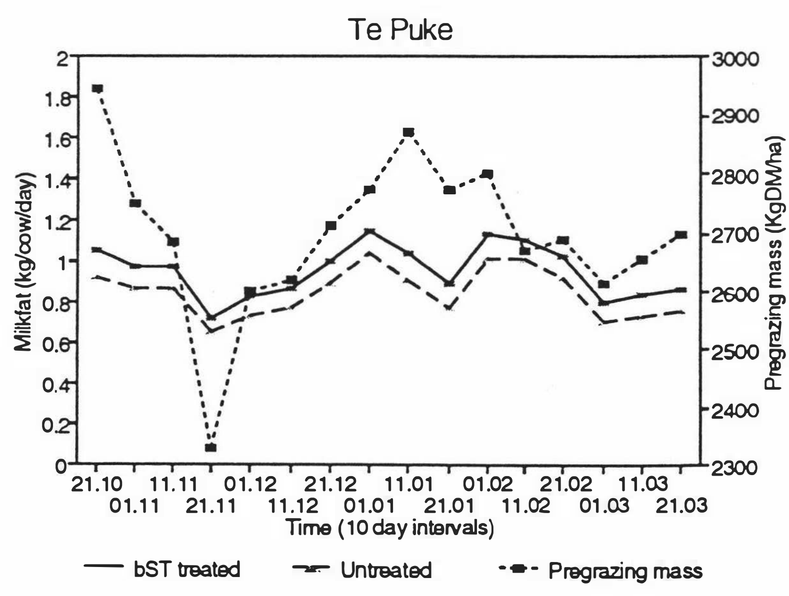

Fig.4. Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Te Puke.

Location: Hamilton
Average herd size: 189
Average effective hectares: 69

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per day	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	2984	1.09	10.89	0.95	9.47	0.142	12.47
01.11	3037	1.17	11.65	1.02	10.21	0.144	12.64
11.11	2866	1.11	11.11	0.98	9.84	0.127	11.15
21.11	2837	1.10	11.04	0.98	9.80	0.124	10.89
01.12	2712	0.92	9.19	0.81	8.11	0.108	9.48
11.12	2630	0.88	8.77	0.78	7.79	0.098	8.6
21.12	2422	0.78	7.84	0.71	7.12	0.072	6.32
01.01	2154	0.69	6.88	0.65	6.50	0.038	3.34
11.01	2295	0.61	6.09	0.55	5.53	0.056	4.92
21.01	2027	0.34	3.37	0.31	3.15	0.022	1.93
01.02	2146	0.64	6.38	0.60	6.01	0.037	3.25
11.02	2020	0.62	6.24	0.60	6.03	0.021	1.84
21.02	2111	0.60	5.99	0.57	5.66	0.033	2.9
01.03	2079	0.40	4.04	0.37	3.75	0.029	2.55
11.03	2160	0.46	4.65	0.43	4.26	0.039	3.42
21.03	2240	0.52	5.25	0.48	4.76	0.049	4.3
01.04							
Total			119.38		107.99	1.139	100

difference (kgMF) 11.39
% response to bST 10.6

Table 19. Likely response to bST under average conditions in Hamilton obtained by fitting bST response function to simulated pasture mass data.

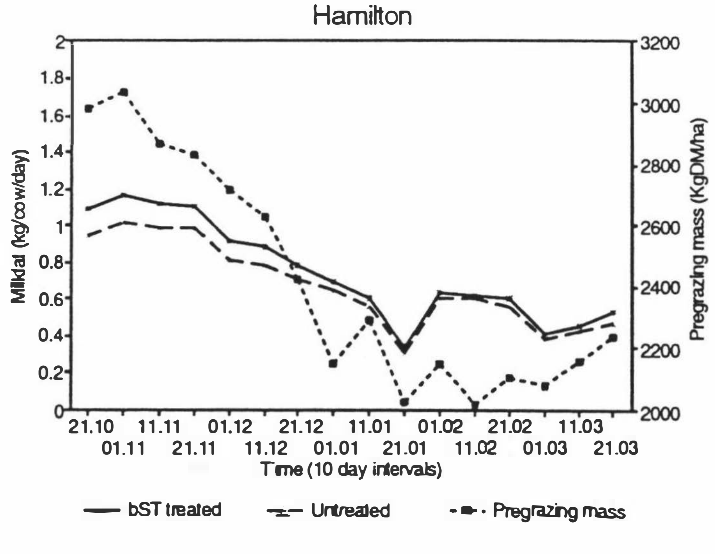

Fig.5. Comparison of expected Milkfat production in bST treated and control groups against average pasture cover in Hamilton.

Location: Stratford
Average herd size: 154
Average effective hectares: 66

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per dy	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	2045	0.38	3.82	0.36	3.58	0.025	1.95
01.11	2238	0.59	5.92	0.54	5.43	0.049	3.82
11.11	2246	0.65	6.45	0.60	5.95	0.05	3.89
21.11	2457	0.82	8.18	0.74	7.42	0.076	5.92
01.12	2545	0.79	7.93	0.71	7.06	0.087	6.78
11.12	2539	0.81	8.08	0.72	7.22	0.086	6.7
21.12	2819	1.08	10.82	0.96	9.61	0.121	9.42
01.01	2676	1.08	10.81	0.98	9.77	0.103	8.02
11.01	2818	1.00	10.03	0.88	8.81	0.121	9.42
21.01	2663	0.82	8.16	0.71	7.14	0.102	7.94
01.02	2720	1.07	10.70	0.96	9.61	0.109	8.49
11.02	2520	1.00	10.00	0.92	9.16	0.084	6.54
21.02	2566	0.94	9.41	0.85	8.51	0.09	7.01
01.03	2538	0.75	7.49	0.66	6.63	0.086	6.7
11.03	2611	0.80	8.04	0.71	7.09	0.095	7.4
21.03	2459	0.69	6.90	0.61	6.13	0.076	5.92
01.04							
Total			125.85		113.00	1.284	100

Difference (kgMF) 12.85
% response to bST —- 11.4

Table 20. Likely response per cow to bST under average conditions in Stratford obtained by fitting bST response function to simulated pasture mass data.

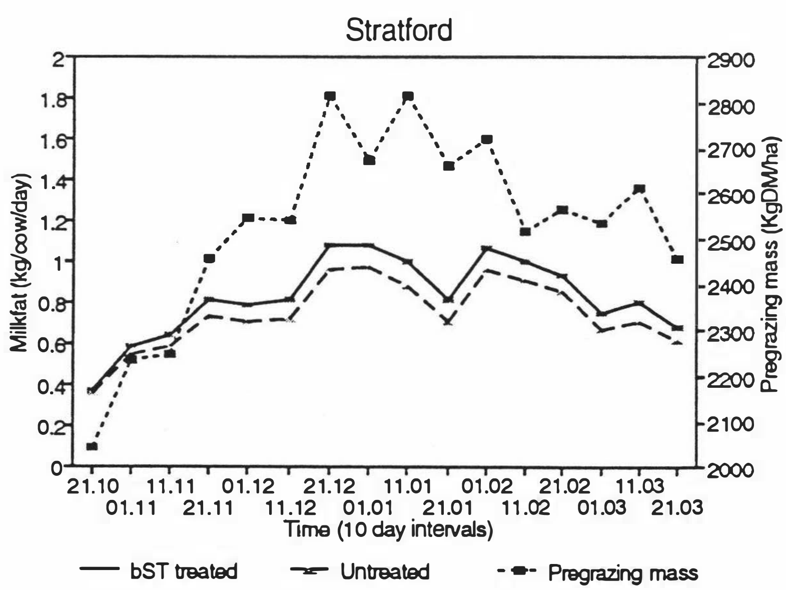

Fig.6. Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Stratford.

Location: Manaia
Average herd size: 184
Average effective hectares: 70

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per dy	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10	2596						
21.10	2532	0.75	7.49	0.66	6.63	6.823	3.63
01.11	2632	0.89	8.89	0.79	7.80	8.095	4.18
11.11	2743	1.02	10.19	0.91	9.03	9.282	4.78
21.11	2991	1.22	12.20	1.08	10.68	11.121	6.1
01.12	3150	1.14	11.35	0.99	10.83	10.363	6.14
11.12	2991	1.15	11.48	1.01	10.20	10.477	6.12
21.12	2985	1.21	12.07	1.07	9.59	11.008	6.07
01.01	2887	1.24	12.40	1.11	10.04	11.286	5.55
11.01	2895	1.06	10.61	0.93	10.62	9.676	5.59
21.01	2522	0.71	7.10	0.63	8.81	6.47	3.58
01.02	2752	1.09	10.94	0.98	9.77	9.959	4.82
11.02	2589	1.05	10.52	0.96	8.27	9.563	3.97
21.02	2719	1.06	10.56	0.95	9.34	9.615	4.65
01.03	2627	0.82	8.16	0.72	9.03	7.442	4.14
11.03	2677	0.85	8.54	0.75	9.84	7.786	4.44
21.03	2665	0.84	8.45	0.74	10.27	7.704	4.35
01.04							
Total			160.93		142.63	1.83	100

Difference (kgMF) 18.30
% response to bST — 13

Table 21. Likely response per cow to bST under average conditions in Manaia obtained by fitting bST response function to simulated pasture mass data.

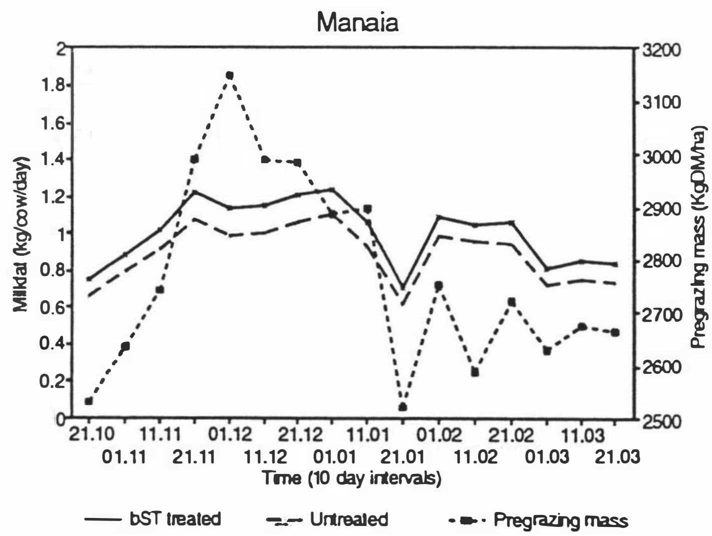

Fig.7. Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Manaia.

Location: Wanganui
Average herd size: 225
Average effective hectares: 100

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per dy	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	2722	0.89	8.91	0.78	7.82	0.109	11.24
01.11	2720	0.95	9.55	0.85	8.46	0.109	11.24
11.11	2655	0.95	9.53	0.85	8.52	0.101	10.41
21.11	2630	0.95	9.48	0.85	8.51	0.098	10.11
01.12	2532	0.78	7.83	0.70	6.98	0.085	8.76
11.12	2496	0.78	7.76	0.69	6.95	0.081	8.35
21.12	2371	0.75	7.45	0.68	6.80	0.065	6.7
01.01	2218	0.74	7.36	0.69	6.90	0.046	4.74
11.01	2402	0.69	6.90	0.62	6.20	0.069	7.11
21.01	2166	0.44	4.42	0.40	4.02	0.04	4.12
01.02	2272	0.73	7.33	0.68	6.80	0.053	5.46
11.02	2120	0.70	6.99	0.67	6.65	0.034	3.51
21.02	1989	0.49	4.90	0.49	4.90	0	0
01.03	1967	0.30	3.05	0.30	3.05	0	0
11.03	2160	0.46	4.65	0.43	4.26	0.039	4.02
21.03	2180	0.48	4.80	0.44	4.38	0.041	4.23
01.04							
Total			110.91		101.20	0.97	100

Difference (kgMF) 9.71
% response to bST — 10

Table 22. Likely response per cow to bST under average conditions in Wanganui obtained by fitting bST response function to simulated pasture mass data.

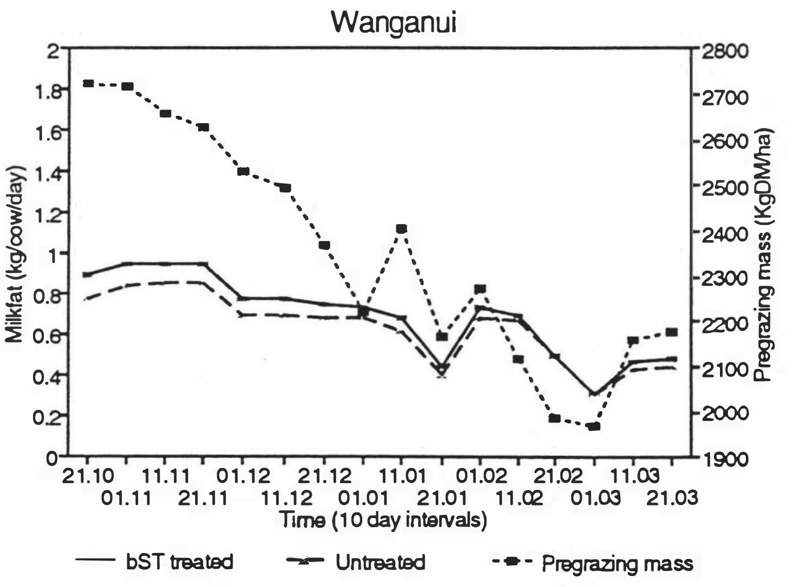

Fig.8. Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Wanganui.

Location: Palmerston North
Average herd size: 260
Average effective hectares: 102

		bST treated		Control			Percentage
Date	Pasture mass (kgDM/ha)	KgMF/cow per day	Total MF for pd.	KgMF/cow per dy	Total MF for pd.	Difference (kg/cow/d)	of total response
11.10							
21.10	2479	0.71	7.09	0.63	6.30	0.079	8.08
01.11	2772	0.99	9.94	0.88	8.78	0.115	11.76
11.11	2845	1.10	10.96	0.97	9.71	0.125	12.78
21.11	2723	1.02	10.18	0.91	9.09	0.109	11.15
01.12	2740	0.94	9.40	0.83	8.28	0.111	11.35
11.12	2571	0.83	8.32	0.74	7.42	0.09	9.2
21.12	2460	0.81	8.12	0.74	7.36	0.076	7.77
01.01	2153	0.69	6.87	0.65	6.49	0.038	3.89
11.01	2261	0.58	5.84	0.53	5.32	0.052	5.32
21.01	1962	0.27	2.74	0.27	2.74	0	0
01.02	2066	0.58	5.78	0.55	5.51	0.027	2.76
11.02	2044	0.64	6.42	0.62	6.18	0.024	2.45
21.02	2083	0.58	5.78	0.55	5.48	0.029	2.97
01.03	2094	0.42	4.15	0.38	3.84	0.031	3.17
11.03	2130	0.44	4.42	0.41	4.07	0.035	3.58
21.03	2145	0.45	4.53	0.42	4.16	0.037	3.77
01.04							
Total			110.55		100.74	0.978	100

Difference (kgMF) 9.81
% response to bST — 10

Table 23. Likely response per cow to bST under average conditions in Pamerston North obtained by fitting bST response function to simulated pasture mass data.

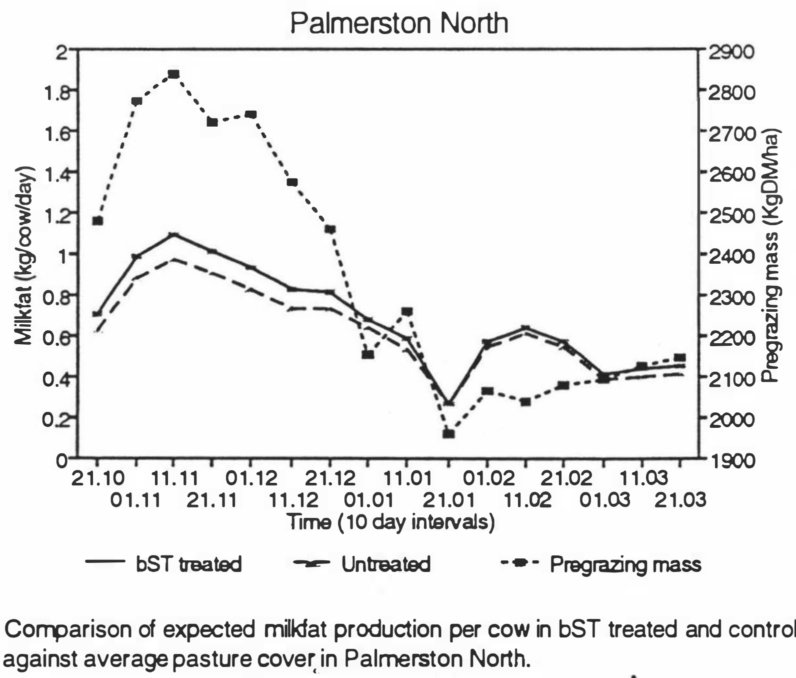

Fig.9 Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Palmerston North.

Location: Masterton
Average herd size: 184
Average effective hectares: 75

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per dy	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	2830	0.97	9.73	0.85	8.50	0.123	14.89
01.11	2788	1.01	10.06	0.89	8.88	0.117	14.17
11.11	2688	0.98	9.78	0.87	8.73	0.105	12.71
21.11	2805	1.08	10.80	0.96	9.60	0.12	14.53
01.12	2684	0.90	8.98	0.79	7.93	0.104	12.59
11.12	2615	0.87	8.65	0.77	7.70	0.096	11.62
21.12	2373	0.75	7.47	0.68	6.81	0.066	7.99
01.01	2150	0.69	6.85	0.65	6.47	0.038	4.6
11.01	2082	0.45	4.49	0.42	4.20	0.029	3.51
21.01	1878	0.22	2.21	0.22	2.21	0	0
01.02	1859	0.42	4.21	0.42	4.21	0	0
11.02	1888	0.52	5.20	0.52	5.20	0	0
21.02	1896	0.43	4.31	0.43	4.31	0	0
01.03	1950	0.29	2.94	0.29	2.94	0	0
11.03	2076	0.40	4.02	0.37	3.73	0.028	3.39
21.03	1881	0.25	2.51	0.25	2.51	0	0
01.04							
Total			102.20		93.94	0.826	100

Difference (kgMF) 8.26
% response to bST — 9

Table 24. Likely response per cow to bST under average conditions in Masterton obtained by fitting bST response function to simulated pasture mass data.

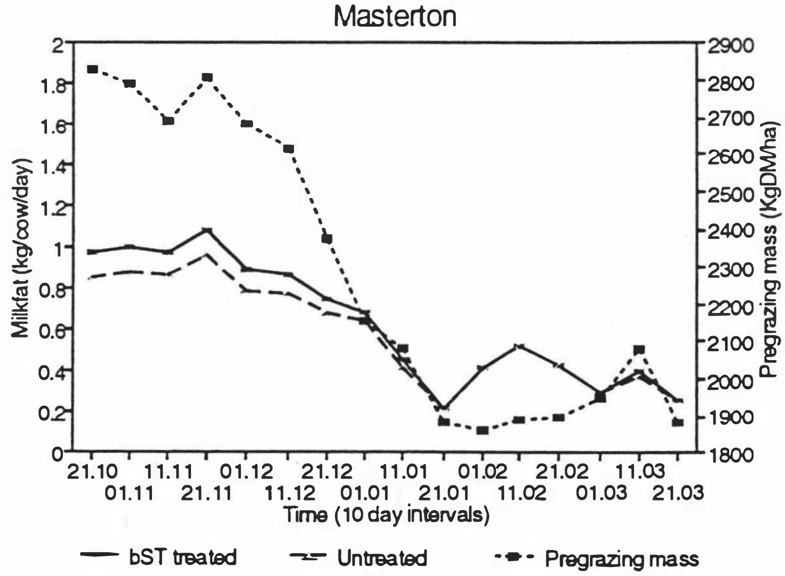

Fig.10. Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Masterton.

Location: Winchmore - Dry
Average herd size: 235
Average effective hectares: 101

Date	bST treated			Control			Percentage
	Pasture mass (kgDM/ha)	KgMF/cow per day	Total MF for pd.	KgMF/cow per day	Total MF for pd.	Difference (kg/cow/d)	of total response
11.10							
21.10	2090	0.42	4.16	0.39	3.86	0.03	29.13
01.11	2041	0.44	4.44	0.42	4.20	0.024	23.3
11.11	2078	0.52	5.19	0.49	4.90	0.029	28.16
21.11	2010	0.48	4.82	0.46	4.62	0.02	19.41
01.12	1958	0.34	3.38	0.34	3.38	0	0
11.12	1849	0.29	2.89	0.29	2.89	0	0
21.12	1801	0.32	3.23	0.32	3.23	0	0
01.01	1729	0.38	3.83	0.38	3.83	0	0
11.01	1740	0.21	2.05	0.21	2.05	0	0
21.01	1715	0.12	1.19	0.12	1.19	0	0
01.02	1771	0.37	3.66	0.37	3.66	0	0
11.02	1837	0.49	4.88	0.49	4.88	0	0
21.02	1909	0.44	4.39	0.44	4.39	0	0
01.03	1969	0.31	3.06	0.31	3.06	0	0
11.03	1935	0.28	2.85	0.28	2.85	0	0
21.03	1928	0.28	2.80	0.28	2.80	0	0
01.04							
Total			56.62		55.79	0.103	100

Difference (kgMF) 1.03
% response to bST 1.9

Table 25. Likely response per cow to bST treatment under average conditions in Winchmore obtained by fitting bST response function to simulated pasture mass data.

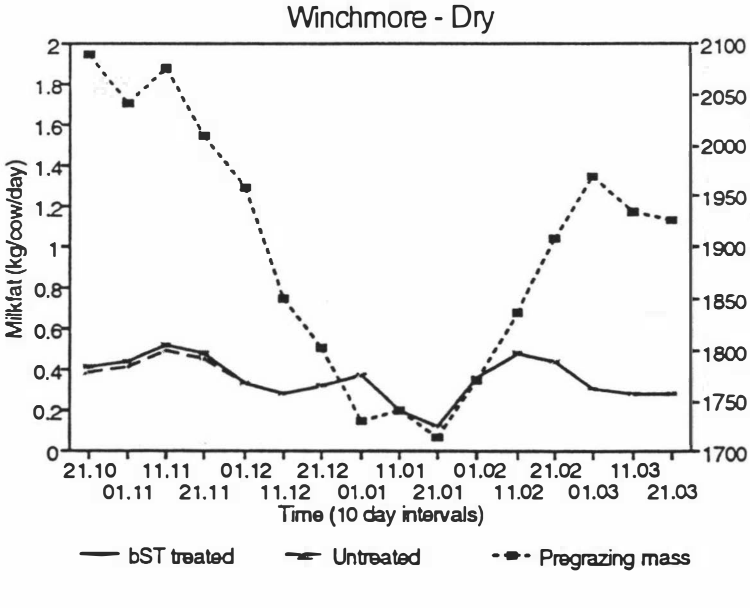

Fig.11. Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Winchmore.

Location: Winchmore - Irrigated
Average herd size: 235
Average effective hectares: 101

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per day	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	1999	0.33	3.29	0.33	3.29	0	0
01.11	2030	0.44	4.36	0.41	4.13	0.023	3.23
11.11	2062	0.51	5.07	0.48	4.80	0.027	3.78
21.11	1882	0.38	3.81	0.38	3.81	0	0
01.12	1821	0.25	2.52	0.25	2.52	0	0
11.12	1913	0.33	3.29	0.33	3.29	0	0
21.12	1913	0.39	3.93	0.39	3.93	0	0
01.01	2036	0.60	5.99	0.58	5.76	0.023	3.23
11.01	2121	0.48	4.78	0.44	4.44	0.034	4.77
21.01	2279	0.53	5.27	0.47	4.73	0.054	7.57
01.02	2488	0.90	8.95	0.82	8.15	0.08	11.22
11.02	2716	1.15	11.48	1.04	10.39	0.108	15.15
21.02	2601	0.97	9.67	0.87	8.73	0.094	13.18
01.03	2678	0.85	8.54	0.75	7.51	0.104	14.59
11.03	2578	0.78	7.79	0.69	6.88	0.091	12.76
21.03	2452	0.68	6.84	0.61	6.09	0.075	10.52
Total			95.60		88.46	0.713	100

Difference (kgMF) --- 7.14
% response to bST --- 8.1

Table 26. Likely response per cow to bST treatment under average conditions in in Winchmore (irrigated) obtained by fitting bST response function to pasture mass data.

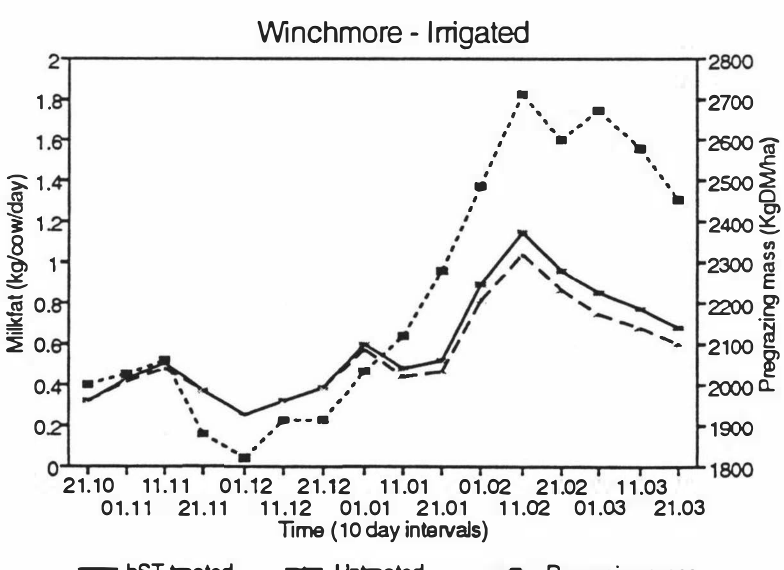

Fig.12.Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Winchmore - Irrigated pasture.

Location: Invermay
Average herd size: 217
Average effective hectares: 101

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per dy	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	2164	0.47	4.72	0.43	4.32	0.039	3.24
01.11	2260	0.61	6.09	0.56	5.57	0.051	4.24
11.11	2330	0.71	7.08	0.65	6.48	0.06	4.99
21.11	2456	0.82	8.17	0.74	7.41	0.076	6.32
01.12	2537	0.79	7.87	0.70	7.01	0.086	7.15
11.12	2617	0.87	8.67	0.77	7.71	0.096	7.98
21.12	2621	0.93	9.34	0.84	8.37	0.097	8.06
01.01	2571	1.00	10.02	0.91	9.12	0.09	7.48
11.01	2534	0.79	7.89	0.70	7.03	0.086	7.15
21.01	2415	0.63	6.29	0.56	5.58	0.071	5.9
01.02	2402	0.83	8.31	0.76	7.62	0.069	5.74
11.02	2368	0.89	8.86	0.82	8.21	0.065	5.4
21.02	2411	0.82	8.25	0.75	7.54	0.07	5.82
01.03	2413	0.66	6.55	0.58	5.84	0.071	5.9
11.03	2469	0.70	6.97	0.62	6.20	0.078	6.48
21.03	2632	0.82	8.20	0.72	7.22	0.098	8.15
01.04							
Total			123.27		111.23	1.203	100

Difference (kgMF) 12.04
% response to bST — 10.8

Table 27. Likely response per cow to bST under average conditions in Invermay obtained by fitting bST response function to simulated pasture mass data.

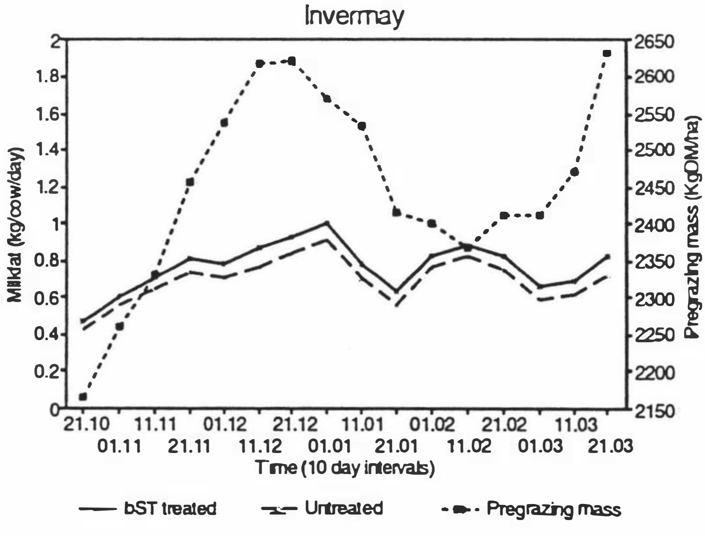

Fig.13. Comparison of expected milkfat production per cow in bST treated and control groups against average pasture cover in Invermay.

Location: Gore
Average herd size: 224
Average effective hectares: 110

Date	Pasture mass (kgDM/ha)	bST treated KgMF/cow per day	bST treated Total MF for pd.	Control KgMF/cow per day	Control Total MF for pd.	Difference (kg/cow/d)	Percentage of total response
11.10							
21.10	1918	0.28	2.78	0.28	2.78	0	0
01.11	1891	0.33	3.26	0.33	3.26	0	0
11.11	1946	0.41	4.07	0.41	4.07	0	0
21.11	2114	0.56	5.60	0.53	5.27	0.033	2.12
01.12	2267	0.58	5.84	0.53	5.32	0.052	3.35
11.12	2471	0.76	7.57	0.68	6.79	0.078	5.02
21.12	2681	0.98	9.79	0.87	8.75	0.104	6.7
01.01	2920	1.26	12.64	1.13	11.30	0.134	8.63
11.01	3127	1.14	11.40	1.00	9.96	0.144	9.27
21.01	3374	1.07	10.69	0.93	9.25	0.144	9.27
01.02	3582	1.28	12.81	1.14	11.37	0.144	9.27
11.02	3562	1.36	13.61	1.22	12.17	0.144	9.27
21.02	3657	1.27	12.68	1.12	11.24	0.144	9.27
01.03	3634	1.10	10.97	0.95	9.53	0.144	9.27
11.03	3719	1.10	10.97	0.95	9.53	0.144	9.27
21.03	3709	1.10	10.97	0.95	9.53	0.144	9.27
01.04							
Total			145.63		130.10	1.553	100

Difference (kgMF)	15.54
% response to bST	12

Table 28. Likely response per cow to bST under average conditions in Gore obtained by fitting bST response function to simulated pasture mass data.

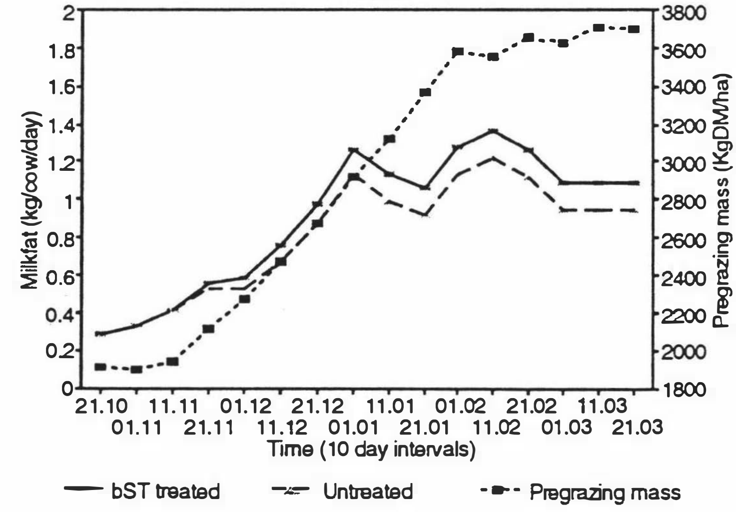

Fig.14. Comparison of expected milkfat production per cow in bST treated and control groups in Gore against pasture cover.

Location: Greymouth
Average herd size: 178
Average effective hectares: 101

		bST treated		Control			Percentage
Date	Pasture mass (KgDM/ha)	KgMF/cow per day	Total MF for pd.	KgMF/cow per day	Total MF for pd.	Difference (kg/cow/d)	of total response
11.10							
21.10	1686	0.13	1.32	0.13	1.32	0	0
01.11	1717	0.22	2.17	0.22	2.17	0	0
11.11	1826	0.33	3.32	0.33	3.32	0	0
21.11	1963	0.43	4.32	0.43	4.32	0	0
01.12	2109	0.47	4.65	0.43	4.33	0.033	2.85
11.12	2245	0.59	5.87	0.54	5.37	0.05	4.33
21.12	2392	0.76	7.61	0.69	6.93	0.068	5.88
01.01	2600	1.02	10.24	0.93	9.30	0.094	8.13
11.01	2781	0.97	9.75	0.86	8.58	0.117	10.12
21.01	2713	0.85	8.53	0.75	7.45	0.108	9.35
01.02	2801	1.13	11.31	1.01	10.12	0.119	10.29
11.02	2769	1.19	11.88	1.07	10.73	0.115	9.95
21.02	2800	1.12	11.17	1.00	9.98	0.119	10.29
01.03	2753	0.91	9.11	0.80	7.98	0.113	9.78
11.03	2757	0.91	9.14	0.80	8.00	0.114	9.86
21.03	2696	0.87	8.68	0.76	7.62	0.106	9.17
01.04							
Total			119.07		107.52	1.156	100

Difference (kgMF)	11.56
% response to bST	11

Table 29. Likely response per cow to bST under average conditions in Greymouth obtained by fitting bST response function to simulated pasture mass data.

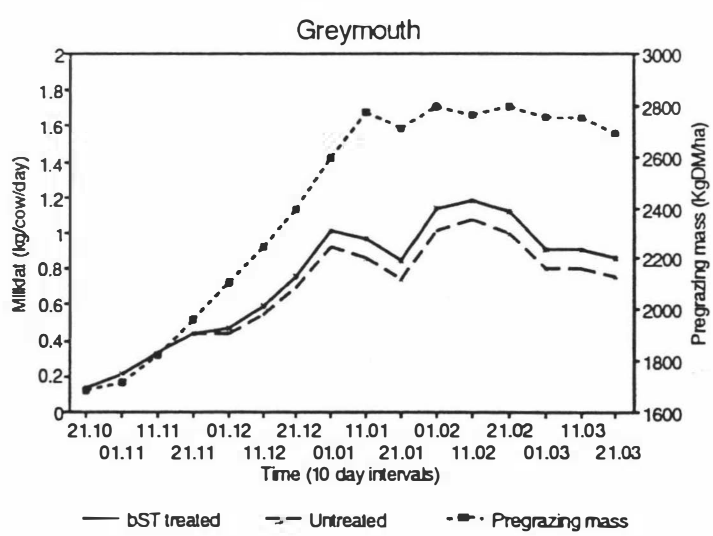

Fig.15 Comparison of expected milkfat production per cow in bST treated and control groups in Greymouth against pasture cover.

milkfat production from bST is commercially viable for farmers to adopt the technology.

5.5 Returns to bST use

The preceding section sought to establish the likely response to bST use in a forage based system in twelve different locations in New Zealand. Estimates indicate an eight to fourteen percent expected increase in milkfat production with bST from grazed pasture in the selected locations. As described in Chapter 1, the New Zealand dairy farmer receives minimal government assistance for his farming business. In this efficient and competitive farming environment farmers are unlikely to adopt new technology like bST, unless at the time of adoption they perceive an acceptable return after costs for their time and management. This section will develop an understanding of whether or not the estimated increases in milkfat production with bST would provide a minimum threshold return to farmers.

Following the view of Marion and Wills (1990), if administering bST is relatively simple and management requirements are not too high an additional $ 2000.00 to $ 4000.00 per herd may be a reasonable incentive to adopt bST. Considering the higher value of $ 4000.00 for an average New Zealand herd of 187 cows (NZDB.1993/94) and for a bST treatment period of 150 days (total lactation length = 230) this figure will translate to approximately $ 0.15 per cow per day. Since it is not known what return farmers might require this study will consider $ 0.15 per cow per day as the minimum inducement to a New Zealand dairy farmer for his risk and management. The estimated extra milkfat output from bST use from the previous section for the twelve locations being considered in this study will be used to test the expected return to management. This study will use expected return to management as the basis for evaluating likely adoption of bST in New Zealand dairy farms. Unlike concentrate feeding systems, feed supply is not uniform in forage-based dairy management systems due to uncertainties of weather. Thus for a better understanding of the use of bST in such a system the total assumed bST treatment period of 150 days will be split into five of 30 day bST treatment blocks. The return to management can be separately estimated for each block to identify any feasible periods that may be masked if the 150 day treatment period were to be considered as a whole.

As discussed in Chapter 4.4 the extra labour requirement of 0.20 mandays (1.6 hours) per cow will be proportionately distributed for each 30 day block being considered. Other variable costs including additional animal health costs are estimated at \$ 0.05 per cow per day amounting to \$ 7.50 per cow for a bST treatment period of 150 days. The price per kilogram of milk fat is assumed \$6.50. All other assumptions and details are in Chapter 4.4.

Referring to Chapter 4.3 the farm decision model will take the form:

Incremental Revenue = % incremental milkfat production * Price of milkfat

$$\text{Incremental costs} + \text{Return to mgt.} = \text{Cost of bST} + \text{extra labour cost} + \text{other Variable costs} + \text{return to mgt.}$$

Therefore, at the point of receiving the minimum inducement to management of $ 0.15 per cow per day,

Incremental revenue - Incremental costs = 0

Boxes 1 and 2 (pages 77 to 78) shows in more detail the organisation of this farm decision model.

Also relevant, is the fact that bST is a technology that can be turned "on" or "off" at will (McCutcheon *et al*, 1985). Literature does not suggest any cumulative hormonal effect during the lactation cycle influencing milk production. Thus each bST treatment period is independent of the other. Response is dependent only on the level of bST concentration in the system at a given time (Chapter 2). However, literature suggests that response to bST could be obtained within a few days of treatment. Therefore, bST treatment can be manipulated in the lactation cycle when conditions are favourable for a response for adequate return. A summary of revenues and costs for the 12 locations are considered separately. A breakdown for each of the five bST treatment periods is presented for evaluation.

5.5.1 Returns to bST use in Warkworth

Consistent pasture growth in Warkworth (fig. 3) is conducive to high pasture covers throughout the bST treatment period of 150 days providing sufficient energy to the cow for a response to treatment. The expected return to management over the whole treatment period is more than three fold greater than the base required return to management of $0.15 per cow per day. It is apparent (table 30) that bST could be profitably used throughout the 150 day bST treatment period in Warkworth.

Warkworth (Average herd size = 170)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	4.33	28.145	12.70	15.45	0.52
31-60	2	4.33	28.145	12.70	15.45	0.52
61-90	3	4.33	28.145	12.70	15.45	0.52
91-120	4	4.33	28.145	12.70	15.45	0.52
121-150	5	4.33	28.145	12.70	15.45	0.52

Total returns to mgt./cow $ = 77.45

Total herd returns to mgt.$ = 13132.50

Average returns to mgt./cow/day $ = 0.52

Table 30. Returns to bST use under average conditions in Warkworth

5.5.2 Returns to bST use in Te Puke

As was observed for Warkworth a well spread pasture growth pattern for Te Puke (fig. 4) provides sizeable return to bST use (table 31). However, in bST treatment period two the return to management is $ 0.11 per cow per day lower than the minimum inducement. Since periods 1 and 3 provide good return to bST use, treatment can be continued through period 2 even with smaller than required return to management as it adds to total revenue. The average return from bST use for Te Puke is $ 0.34 per cow per day two fold greater than the required

Total lactation length = 230 days

Treatment period = 150 days
(commencing 10-12 wks. post partum)

<u>Incremental revenue Assumptions</u>

Price of milkfat $/kg	= 6.50
Incremental milkfat production (kg/cow)	
Treatment period 1	= 2.95
Treatment period 2	= 4.30
Treatment period 3	= 4.03
Treatment period 4	= 2.90
Treatment period 5	= 4.12
Herd size	= 184

Calculation:

Incremental revenue ($):

	$
Treatment period 1: 2.95kg x $ 6.50	= 19.18
Treatment period 2: 4.30kg x $ 6.50	= 27.95
Treatment period 3: 4.03kg x $ 6.50	= 26.19
Treatment period 4: 2.90kg x $ 6.50	= 18.85
Treatment period 5: 4.12kg x $ 6.50	= 26.78
Total incremental revenue/cow	= <u>118.95</u>

<u>Incremental cost assumptions:</u>

bST treatment cost /30 days/cow $	= 8.00
Extra labour requirement for 150 days(man/days) (=1.6 hrs/cow)	= 0.20
Labour cost $/hour	= 10.00
Other variable costs (health etc.) $/cow'day	= 0.05

Box 1. Illustration of farm decision model for bST use in Manaia.

Calculation:

Incremental cost/cow (for 30 day treatment period):

Price of bST (per dose) $	= 8.00
Extra labour cost $ (1.6hrs x (30/150) x $10.00)	= 3.20
Other variable costs ($0.05 x 30)$	= 1.50
Total incremental cost/cow (30 days)	= 12.70

Calculation of returns to management:

Assumptions:

Required returns to management ($/cow/day) = 0.15

Incremental revenue = Incremental milkfat x Price of milkfat
(30 days)

Incremental cost = Price of bST/treatment + extra labour cost + other variable costs
(30 days)

Incremental revenue - Incremental costs = Returns to Management
(30 days) (30 days) (30 days)

Decision to adopt bST: Returns to management >= $ 0.15/cow/day

Calculation:

Incr.rev - Inc.cost = Returns to mgt.

Period 1: $ 19.18 - 12.70 = $ 6.48 = $ 0.21/cow/day
Period 2: $ 27.95 - 12.70 = $ 15.25 = $ 0.50/cow/day
Period 3: $ 26.19 - 12.70 = $ 13.49 = $ 0.44/cow/day
Period 4: $ 18.85 - 12.70 = $ 6.15 = $ 0.20/cow/day
Period 5: $ 26.78 - 12.70 = $ 14.08 = $ 0.47/cow/day

Av. returns/cow = $ 55.45 = $ 0.37/cow/day

Box 2. Illustration of farm decision model for bST use in Manaia (cont.)

return to management. Though the return to management in Te Puke is less than for Warkworth results (table 31) indicate that bST could be used with adequate return throughout the potential treatment period of 150 days.

Te Puke (herd size = 196)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	3.53	22.95	12.70	10.25	0.34
31-60	2	2.05	16.25	12.70	3.55	0.11
61-90	3	4.24	27.56	12.70	14.86	0.49
91-120	4	3.37	21.91	12.70	9.26	0.30
121-150	5	4.07	26.46	12.70	13.76	0.45

Total returns to mgt./cow $ = 51.68

Total herd returns to mgt. $ = 10129.28

Average returns to mgt./cow/day $ = 0.34

Table 31. Returns to bST use under average conditions in Te Puke

5.5.3 Returns to bST use in Hamilton

Results generated for Hamilton (table 32) indicate that bST use in treatment periods 3, 4 and 5 does not produce sufficient milkfat to allow for incremental costs. The low rainfall and high temperatures during the summer months restrict pasture growth and therefore limit the response to bST. However, treatment periods 1 and 2 provide adequate return to make bST profitable during that period. An average return to management of $ 0.30 per cow per day is obtained during the first 60 days of bST use. Results suggest that bST use under average conditions in Hamilton can provide an adequate profit only to a limited period of about 60 days from the commencement of bST treatment at peak lactation.

Hamilton (Herd size = 189)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	4.13	26.85	12.70	14.15	0.47
31-60	2	3.30	21.45	12.70	8.75	0.29
61-90	3	1.66	10.79	12.70	-1.91	0
91-120	4	0.88	5.20	12.70	-7.50	0
121-150	5	1.55	9.75	12.70	-2.95	0

Total returns (60 days) to mgt./cow $ = 22.90

Total herd returns (60 days) to mgt. $ = 4327.15

Average returns (60 days) to mgt./cow/day $ = 0.30

Table 32. Returns to bST use under average conditions in Hamilton

5.5.4 Returns to bST use in Manaia (South Taranaki)

Figure 7 shows a well distributed pasture growth pattern in Manaia. Corresponding to pasture supply, returns to bST use (table 33) in Manaia also shows the same trend. The return to management from bST use in all 5 periods is greater than the required return to management. Results suggest that bST use during the 150 day treatment period can enhance farm profits.

Manaia (Herd size = 184)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	2.95	19.18	12.70	6.48	0.21
31-60	2	4.30	27.95	12.70	15.25	0.50
61-90	3	4.03	26.19	12.70	13.50	0.44
91-120	4	2.19	18.85	12.70	6.15	0.20
121-150	5	4.12	26.78	12.70	14.08	0.46

Total returns to mgt./cow $ = 55.46

Total herd returns to mgt. $ = 10202.80

Average returns to mgt./cow/day $ = 0.37

Table 33. Returns to bST use under average conditions in Manaia.

5.5.5 Returns to bST use in Stratford (Cenral Taranaki)

Though in figure 6 a continuous milkfat response to bST use is shown for Stratford, calculation of returns (table 34) indicate that in bST treatment period 1, incremental benefits from use of bST is less than incremental costs. Thus bST use in period 1 is not feasible. Period 2 provides a return to management of $ 0.12 per cow per day and is less than the required return to management. However, since bST treatment periods 3, 4 and 5 show larger returns, period 2 can be combined with these periods for greater total return. The mean return to management during the 120 day effective bST treatment period is $ 0.20 per cow per day. Under average conditions in Stratford the first (30 days) scheduled treatment after peak lactation can be avoided and treatment can commence from period 2 through 5 for a reasonable return to management.

Stratford (Herd size = 154)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	1.24	8.06	12.70	-4.64	0
31-60	2	2.49	16.19	12.70	3.49	0.12
61-90	3	3.45	22.43	12.70	9.72	0.32
91-120	4	2.95	19.175	12.70	6.48	0.22
121-150	5	2.71	17.62	12.70	4.91	0.16

Total returns (120 days) to mgt./cow $ = 24.60

Total herd returns to mgt. $ = 3788.40

Average returns to mgt./cow/day $ = 0.20

Table 34. Returns to bST use under average conditions in Stratford

5.5.6 Returns to bST use in Wanganui

Response to bST in Wanganui (figure 8) is likely only during the early part of the treatment period. If bST were to be used in Wanganui the most profitable period (under average conditions) would be during the first two treatment periods of 60 days commencing peak lactation. The average return to management during the effective treatment period is $ 0.20 per cow per day and this figure exceeds the required return to management. The lower rainfall during the summer months in the second half of lactation are not favourable for bST use.

Wanganui (average herd size = 225)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	3.19	20.74	12.70	8.03	0.26
31-60	2	2.64	17.16	12.70	4.46	0.14
61-90	3	1.80	11.70	12.70	-1.00	0
91-120	4	1.20	7.80	12.70	-4.90	0
121-150	5	0.80	5.20	12.70	-7.50	0

Total returns to mgt./cow $ = 12.49

Total herd revenue to mgt. $ = 2811.37

Average returns to mgt./cow/day $ = 0.20

Table 35. Returns to bST use under average conditions in Wanganui.

5.5.7 Returns to bST use in Palmerston North

For Palmerston North milkfat response to bST (figure 9) declines progressively with the advancing lactation because of poor pasture growth during the dry summer months. Table 36 gives an indication of the likely profitable period to use bST under average conditions in Palmerston North. Extra milkfat production in bST treatment period 1 and 2 has an average return to management of $ 0.25 per cow per day whereas in the balance treatment periods the incremental revenue is insufficient to allow for the incremental costs. If bST were to be used in Palmerston North the likely feasible period is in the early bST treatment periods commencing peak lactation.

Palmerston North (average herd size = 260)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	3.19	20.74	12.70	8.04	0.26
31-60	2	3.10	20.15	12.70	7.45	0.24
61-90	3	1.66	10.79	12.70	-1.91	0
91-120	4	0.51	3.32	12.70	-9.38	0
121-150	5	1.32	8.58	12.70	-4.12	0

Total returns to mgt./cow $ = 15.49

Total herd returns to mgt. $ = 4026.10

Average returns to mgt./cow/day = 0.25

Table 36. Returns to bST under average conditions in Palmerston North

5.5.8 Returns to bST use in Masterton

Figure 10 shows a low pasture mass for grazing animals during the dry summer months in Masterton. Limitations in pasture supply during this period restricts response to bST. If bST were to be used under average conditions in Masterton (table 37) the immediate post peak lactation period is feasible. BST treatment periods 1 and 2 (60 days) provide adequate returns while in treatment periods 3, 4 and 5 the milkfat response is insufficient to allow for the incremental costs. The average return to management during the effective bST treatment period is $ 0.30 per cow per day.

Masterton (average herd size = 184)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $
1-30	1	3.45	22.43	12.70	9.73	0.32
31-60	2	3.20	20.80	12.70	8.10	0.27
61-90	3	1.33	8.65	12.70	-4.06	0
91-120	4	0	0	12.70	-12.70	0
121-150	5	0.28	1.82	12.70	-10.88	0

Total returns (60 days) to mgt./cow $ = 17.83

Total herd returns (60 days) to mgt. $ = 3279.80

Average returns to mgt./cow/day $ = 0.30

Table 37. Returns to bST use under average conditions in Masterton.

5.5.9 Returns to bST use in Winchmore

The inadequate response to bST at Winchmore (figure 11) gives no returns to match the incremental costs of any treatment period. As results indicate (table 38) there is no incentive to use bST under average conditions in Winchmore.

Winchmore (average herd size = 235)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	0.83	5.40	12.70	-7.30	0
31-60	2	0.20	1.30	12.70	-11.4	0
61-90	3	0	0	12.70	-12.7	0
91-120	4	0	0	12.70	-12.7	0
121-150	5	0	0	12.70	-12.7	0

Total returns to mgt./cow $ = 0.00

Total herd returns to mgt. $ = 0.00

Average returns to mgt./cow/day $ = 0.00

Table 38. Returns to bST use under average conditions in Winchmore

Winchmore - irrigated site (herd size = 235)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	0.50	3.25	12.70	-9.45	0
31-60	2	0	0	12.70	-12.70	0
61-90	3	0.57	3.71	12.70	-8.99	0
91-120	4	2.46	15.99	12.70	3.29	0.10
121-150	5	3.64	23.66	12.70	10.96	0.36

Total returns (60 days) to mgt./cow $ = 14.25

Total herd returns (60 days) to mgt. $ = 3348.75

Av. returns (60 days) to mgt./cow/day $ = 0.23

Table 39. Returns to bST use for an irrigated site in Winchmore

A similar analysis was done with pasture growth rates for an irrigated site in Winchmore where pastures were irrigated during the dry summer months. Results are presented in table 39. Good pasture cover during the period of irrigation coinciding with treatment periods 4 and 5 showed some response to bST. The average return to management for the two periods were $ 0.23 per cow per day indicating an incentive to use bST. Results indicate that bST could be used profitably at Winchmore only with irrigation of pastures.

5.5.10 Returns to bST use in Invermay

Invermay (average herd size = 217)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	1.53	9.95	12.70	-2.75	0
31-60	2	2.53	16.45	12.70	3.75	0.12
61-90	3	2.73	17.75	12.70	5.04	0.15
91-120	4	2.25	14.63	12.70	1.93	0.06
121-150	5	3.17	20.61	12.70	7.91	0.25

Total returns (120 days) to mgt./cow $ = 18.62

Total herd returns (120 days) to mgt. $ = 4040.50

Av. herd returns (120 days) to mgt./cow/day $ = 0.15

Table 40. Returns to bST use under average conditions in Invermay

Under average conditions in Invermay (figure 13), response to bST again follows the pasture cover trends and is poor at the early treatment periods but gradually rises towards the end of lactation. No return could be expected in treatment period 1 (table 40). However, return to management gradually rise through the advancing lactation to meet the minimum inducement except in treatment period 4 when returns tend to be marginal. The adequate returns obtained in treatment periods 3 and 5 enable bST to be used in period 4 even with marginal returns as it adds to revenue of the farm. Results for average conditions in Invermay suggest that bST could be used to receive a return to management of $ 0.15 per cow per day for four bST treatment periods. The initial treatment is not feasible at Invermay.

5.5.11 Returns to bST use in Gore

Gore (average herd size = 224)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to Management $/cow/day
1-30	1	0	0	12.70	-12.70	0
31-60	2	1.63	10.60	12.70	-2.11	0
61-90	3	3.82	24.83	12.70	12.13	0.40
91-120	4	4.32	28.08	12.70	15.38	0.51
121-150	5	4.33	28.145	12.70	15.45	0.51

Total returns (90 days) to mgt./cow $ = 42.96

Total herd returns (90 days) to mgt. $ = 9621.92

Av. returns (90 days) to mgt./cow/day $ = 0.48

Table 41. Returns to bST use under average conditions in Gore

For Gore (table 41) there is no response to bST in treatment period 1 and inadequate response in period 2 to allow for incremental costs. However, there is a very high return to management during treatment periods 3, 4 and 5. High pasture covers at this time result in a mean return of $ 0.48 per cow per day. Results indicate that for average conditions in Gore bST use is feasible only for the last three bST treatment periods. The first two treatment periods can be avoided.

5.5.12 Returns to bST in Greymouth

Greymouth (average herd size = 178)

Days	Treatment No.	Incr. Prod. kg/milkfat	Incr. rev. $	Incr. cost $	Incr. rev - incr. cost $	Returns to management $/cow/day
1-30	1	0	0	12.70	-12.70	0
31-60	2	1.51	9.81	12.70	-2.89	0
61-90	3	3.15	20.48	12.70	7.76	0.25
91-120	4	3.53	22.95	12.70	10.25	0.34
121-150	5	3.33	21.65	12.70	8.95	0.29

Total returns (90 days) to mgt./cow $ = 26.97

Total herd returns (90 days) to mgt. $ = 4799.77

Av. returns (90 days) to mgt./cow/day $ = 0.29

Table 42. Returns to bST use under average conditions in Greymouth

Similar to Gore, following pasture cover patterns (figure 15), the likely response to bST treatment under average conditions in Greymouth is concentrated towards the latter part of lactation. There is no response to bST in treatment period 1 and insufficient response received in period 2 to allow for incremental costs of bST use (Table 42). BST use in periods 1 and 2 is not feasible. There is adequate return to management in treatment periods 3, 4 and 5 making bST use feasible for the 90 day period. The mean return to management during the feasible period is $ 0.29.

It is worth noting that this study was based on pasture growth relating to an average year. Since pasture growth is very variable within a site the response to bST could also fluctuate accordingly. For periods with less than average pasture growth there remains a likelihood of a nil response to bST.

5.5.13 Summary - returns to bST use

The previous section (5.3) dealt with estimating the likely response to bST use by applying the bST response function to average pasture mass for the locations under consideration. It is evident from the results that for pasture based dairy management systems the response to bST follows closely pasture growth patterns for the particular location. Section 5.3 also categorised the selected sites into four groups based on the potential response patterns observed with bST use. In this section the feasibility of bST use followed the same trends described earlier except in Stratford. Though the Stratford site showed continuous response to bST over the whole treatment period, the response seen in the initial treatment period was insufficient to offset the incremental costs of bST use. In summary, bST could be used throughout the 150 day treatment period in Warkworth, Te Puke and Manaia. For the remaining North Island sites bST use is feasible during the early treatment periods while for the South Island sites use of bST is favourable during the latter part of lactation. For the dryland site in Cantebury plains (Winchmore) bST use is not feasible for any period unless pasture growth is enhanced by irrigation. Table 43 summarises the feasible periods for bST use and the expected returns during the relevant periods for the twelve sites selected in this study.

5.6 Sensitivity analysis

A sensitivity analysis was performed by varying the assumed values of three key variables; price of milkfat, price of bST and required return to management, to indicate the breakeven extra milkfat response required to meet incremental costs of bST use and the required return to management ($ 0.15/cow/day). Results of the sensitivity analysis are presented in table 44. A second sensitivity analysis was performed for each site by varying the price of milkfat from $ 5.75 to $ 6.75 per kg. of milkfat and the price of bST per dose from $ 7.00 to $ 11.00 to observe the effect of the variables on the return to management. The results of the second sensitivity analysis for the independent sites are presented in Appendix 7. For sites where the response to bST was high the required return to management was apparently insensitive to changes in price of bST and price of milkfat. Where the response to bST was low the sensitivity of return to management arising from changes in price of bST is marked, most often the expected return to management moving below the required return. For Warkworth, Te Puke, Manaia, Gore and Hamilton the price of bST and the price paid for milkfat is relatively insensitive to required return to management for the respective periods being considered in the study. For the other sites the maximum price of bST in relation to price of milkfat for bST use to be feasible is summarised in table 45.

Location	Feasible bST treatment period [1]					Total treatment period (days)	Av. returns to Management ($/cow/day)	Total returns to management ($)
	1	2	3	4	5			
Wakworth	x	x	x	x	x	150	0.52	13132.50
Te Puke	x	x	x	x	x	150	0.34	10129.25
Hamilton	x	x				60	0.30	4327.15
Manaia	x	x	x	x	x	150	0.37	10212.80
Stratford		x	x	x	x	120	0.20	3788.40
Wanganui	x	x				60	0.20	2811.35
Palmerston North	x	x				60	0.21	3333.20
Masterton	x	x				60	0.30	3279.80
Winchmore						0	0.00	0.00
Winchmore - irrigated				x	x	60	0.23	3348.75
Invermay		x	x	x	x	120	0.15	4040.55
Gore			x	x	x	90	0.48	9621.95
Greymouth			x	x	x	90	0.29	4799.75

Table 43. Summary of feasible periods for bST treatment and likely returns to management under average pasture growth and farming conditions for the sites selected in the study.

[1] x = feasible periods for bST treatment

Sensitivity Analysis

Price of bST ($/monthly treatment)	Return to management ($/cow/day)	Price of milkfat ($/kg) 6.00	6.50	7.00
8.00	0.10	2.65	2.45	2.25
	0.15	2.90	2.70	2.50
	0.20	3.15	2.95	2.70
	0.25	3.40	3.15	2.90
	0.30	3.65	3.35	3.10
	0.35	3.90	3.60	3.35
	0.40	4.15	3.80	3.55
9.00	0.10	2.80	2.60	2.40
	0.15	3.05	2.80	2.60
	0.20	3.30	3.05	2.85
	0.25	3.55	3.30	3.05
	0.30	3.80	3.50	3.25
	0.35	4.10	3.75	3.50
	4.00	4.30	4.00	3.70
10.00	0.10	3.00	2.75	2.55
	0.15	3.25	3.00	2.75
	0.20	3.50	3.20	3.00
	0.25	3.75	3.45	3.20
	0.30	4.00	3.65	3.40
	0.35	4.25	3.90	3.60
	0.40	4.50	4.15	3.80

Table 44. Breakeven levels of incremental milkfat required per cow for each bST treatment period of 30 days at different economic conditions.

Location	bST cost $		Price of milkfat $		bST cost $		Price of milkfat $
Stratford	10.00	at	6.75				
Wanganui	8.00	at	6.50	or	9.00	at	6.75
Palmerston North	8.00	at	6.50	or	9.00	at	6.25
Masterton	9.00	at	5.75	or	10.00	at	6.00
Winchmore -irrigated	8.00	at	6.50	or	9.00	at	6.75
Invermay	8.00	at	6.50	or	9.00	at	6.25
Greymouth	10.00	at	6.00	or	11.00	at	6.75

Table 45. Maximum cost of bST and required price for milkfat in order for bST use to be feasible at different locations.

Chapter 6

SUMMARY AND CONCLUSIONS

6.1 Introduction

The organization of the thesis was briefly discussed in Chapter 1. In summary Chapter 1 discussed the nature of the problem and the objectives of this study. Chapter 2 reviewed the literature in relation to bST and the pastoral system of dairy farming in New Zealand. It provides an overview of pasture growth and management, the key feature of pastoral systems. Chapters 3 and 4 looked into the source of data and the methodology adopted in the study. Chapter 5 presented the results of the study. Chapter 5 was in four parts, i.e., simulating pasture growth, estimating a bST response function, estimating likely response with bST use for the selected locations and estimating returns to bST use which provided the indication of incentives to use bST in New Zealand dairy farms.

6.2 Summary

The objective of the study was to perform an ex ante analysis to examine the incentives for use of bST under New Zealand dairy farming conditions. Synthetic bST is being used in the US and several other countries and its widespread use can affect international trade of dairy products. New Zealand being the second largest exporter of dairy produce and being dependent on external markets is in a vulnerable situation if bST use in other major dairying countries were to alter the international trade situation existing at present. BST has not been approved for use in New Zealand and the industry has taken a 'wait and see' policy until more is known of the controversial issues, especially, consumer reaction to milk products from bST treated cows. Fallert and Liebrand (1991) are of the view that for New Zealand and Argentina with a low cost pasture based system and with relatively low milk prices, the benefit from bST technology may not be as great as could be expected in the US. With this background the study attempts to examine the likely profitability of bST use in New Zealand dairy farms. This information will be of importance to policy makers prior to any decision being taken on bST in New Zealand.

Bovine somatotropin (bST) or bovine growth hormone is naturally produced in the cow. It is known to regulate partitioning of nutrients for milk production in genetically superior cows. Literature refers to early experiments where cows injected with natural bST showed increases in milk production. However, because of limitations in extracting natural bST it could not be used on a commercial scale.

In the 1980's, a breakthrough in biotechnology allowed exogenous production of bST using DNA technology. This opened avenues for greater experimentation and potentials for commercial use. Studies suggest that milk production increases of 10 to 30 percent can be expected from treated cows without any apparent effects to the health of the cow or to changes in the composition of milk. Quality of management is reported to be the major factor affecting the magnitude of milk response (Bauman, 1992). Quantity, quality and density of nutrients are determinants of efficacy of bST (Mcguffey *et al.*, 1991).

Though bST has been proved to be an effective tool to increase milk production in cows, there is much controversy about its use. Despite many health organizations having approved bST as safe to humans and to health of cows, critics and consumer advocates have called for a ban on its use.

Studies have shown (Chillard, 1988; Peel *et al.*, 1987) that exogenous bST must be present in the system for sustained increases in milk production. However, because the response to treatment is almost immediate, reaching a maximum by about the sixth day (Bauman, 1992) bST treatment can be manipulated (McCutcheon *et al.*, 1985) to achieve best results. The ability to regulate bST use is of particular interest in pastoral systems of dairy management where treatment can be regulated to pasture growing conditions.

In pasture-based dairy management, particularly where there is no feed supplementation, pasture will be the limiting factor for a milk response to bST. Hoogendoorn *et al.* (1990) conducting a trial on cows grazed on pasture in New Zealand confirmed that adequate pasture must be available for a response to bST. The low energy density in pasture could also restrict the response to bST compared to a concentrate feeding system where energy intake can be regulated by varying feed ingredients. However, some response could be expected from cows fed on pasture as suggested by Hoogendoorn *et al.* (1990) and depending on the location and environmental conditions that influence pasture growth. This study looks at the variability caused by location that may influence the incentives for bST use in New Zealand.

In New Zealand where dairying is spread almost throughout the entire span of the country, the geographical location of dairying can influence the response to bST. Taking this into consideration, the study used twelve different locations from Northland to Southland to identify locational differences to bST influenced by climate. The locational difference was expressed through pasture growth.

A bST response function for a 150 day treatment period for a pasture based system was obtained using the trial from Hoogendoorn *et al.* (1990). Their bST response relationship was derived from pasture mass. The use of the response function ideally requires the availability of pasture mass measurements for the sites. However, pasture mass measurements are not usually available and therefore were simulated using the 'Udder' desk top dairy farm model. The 'Udder' model requires monthly PGR measurements for the simulation process. Published pasture growth rate measurements were available for some of the selected locations. For sites where PGR data were not available the 'GROW' model was used to predict average PGR. Using measured and simulated PGR and average regional farm characteristics the 'Udder' model was used to predict pasture mass for the selected sites. It was then possible to obtain an expected response to bST for the different locations using the bST response function and the pasture mass data. The study indicated particular patterns of response moving from Northland to Southland. For the Northland, Bay of Plenty and Taranaki sites there was a continuous response to bST following good pasture growth. For the other North Island sites of Waikato, Rangitikei, Manawatu and Wairarapa with dry summers and relatively high stocking rates, the response to bST was observed only during the first two to three bST treatments. For the South Island in general the response was different from the North Island where a response was more prominent in the second half of the 150 day treatment period. There was insufficient response to bST in the dry Central Otago site except where pastures were irrigated. It is therefore clear that response to bST at any site is dependent on the environment that influence pasture availability to the cow.

As discussed in Chapter 1, the decision to adopt bST in New Zealand dairy farms will depend on the incentives pertaining to its use. Hence the expected return to management is the determinant of likely adoption in this country. The expected return to bST use was calculated to learn of the profitability for use of bST. A required return to management of $ 0.15 per cow per day with cost of bST at $ 8.00 per treatment and the price of milkfat at $ 6.50 per kg against the expected responses for bST were the parameters used for estimation. For the base case the study indicated that the feasible periods to use bST took a similar trend observed for responses. The trend for the Stratford site varied somewhat in that the first bST treatment was not feasible. A sensitivity analysis indicated that sites with low response to bST were sensitive to changes in cost of bST and price offered for milkfat. Conversely, sites with larger response to bST were relatively insensitive in terms of return to management, to changes in price of bST and price paid for milkfat. This indicates that the response rate influenced by pasture availability to the cow is the major determinant of incentives to use bST.

As discussed earlier, the important feature about bST is that treatment can be manipulated to suit the environmental conditions conducive to any response. The identification of economically feasible periods for bST use in this study shows how bST treatment can be manipulated to achieve the desired management objectives to bST use. The study also indicates that bST can be used profitably with existing farm resources. As seen from Chapter 5 if bST treatment were properly timed to match periods of good pasture growth, reasonable returns can be expected from bST for potential users even for short durations. It is not known whether New Zealand dairy farms use optimum stocking rates. Use of lower stocking rates especially in the North Island sites with dry summers may help to bring about more suitable conditions for bST use.

The study indicates that milk production increases ranging from 8 to 14 percent can be expected from New Zealand dairy farms using existing farm resources. These productivity gains per cow would reduce the cost per unit of milk output and could help New Zealand remain competitive in international trade if bST were to be used by other dairy producing countries, leading to lower price of milk products in the world market. The implications of these production increases to the dairy industry at regional and national level is beyond the scope of this study and needs to be investigated separately.

Finally, it must be stressed that the results of this study may not be applicable to individual dairy farms but provides an ex ante evaluation of the potential for bST use in the dairy regions under consideration.

6.3 Implications to dairy farming in New Zealand

The potential of bST in the conventional grazed dairy farming system in New Zealand was demonstrated through the results of this study. The findings are of particular interest to potential users of bST in achieving productivity gains from seasonal herds employing existing farm resources. The flexibility of bST treatment enables it to be used in periods with adequate nutrition to the cow. The selective treatment will only help dairy farmers to enhance their farm profits. The most appropriate period for bST use in different dairying regions was outlined in this study as a guide to potential users. The bST treatment period could vary from 60 to 150 days and the range of extra income from bST use could vary from $ 2800.00 to $ 14,000.00 depending on location. The maximum benefits to dairy farmers through the use of bST could be expected in Northland, Bay of Plenty, Taranaki and Southland. The other dairying regions could expect lower but substantial returns to warrant its use. The greater implication is the lower cost per unit of milk output from productivity gains.

6.4 Suggestions for further research

The study was based on a single bST trial conducted in New Zealand on cows grazed on pasture. The milk response measurements were done against a single level of pasture mass. It did not consider the effect of bST at different levels of pasture allowance to the cow at different stages of the lactation cycle. A more reliable and widely acceptable bST response function can be obtained if more is known on bST response at different pasture allowance to the cow.

This study provides the returns that could be expected by dairy farmers if bST were to be used in New Zealand. The information can be used to survey the attitudes of dairy farmers and the likely adoption rates on New Zealand dairy farms. The results of such a survey will be of use to evaluate the implications that bST can have on the dairy industry of New Zealand.

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Appendix 1

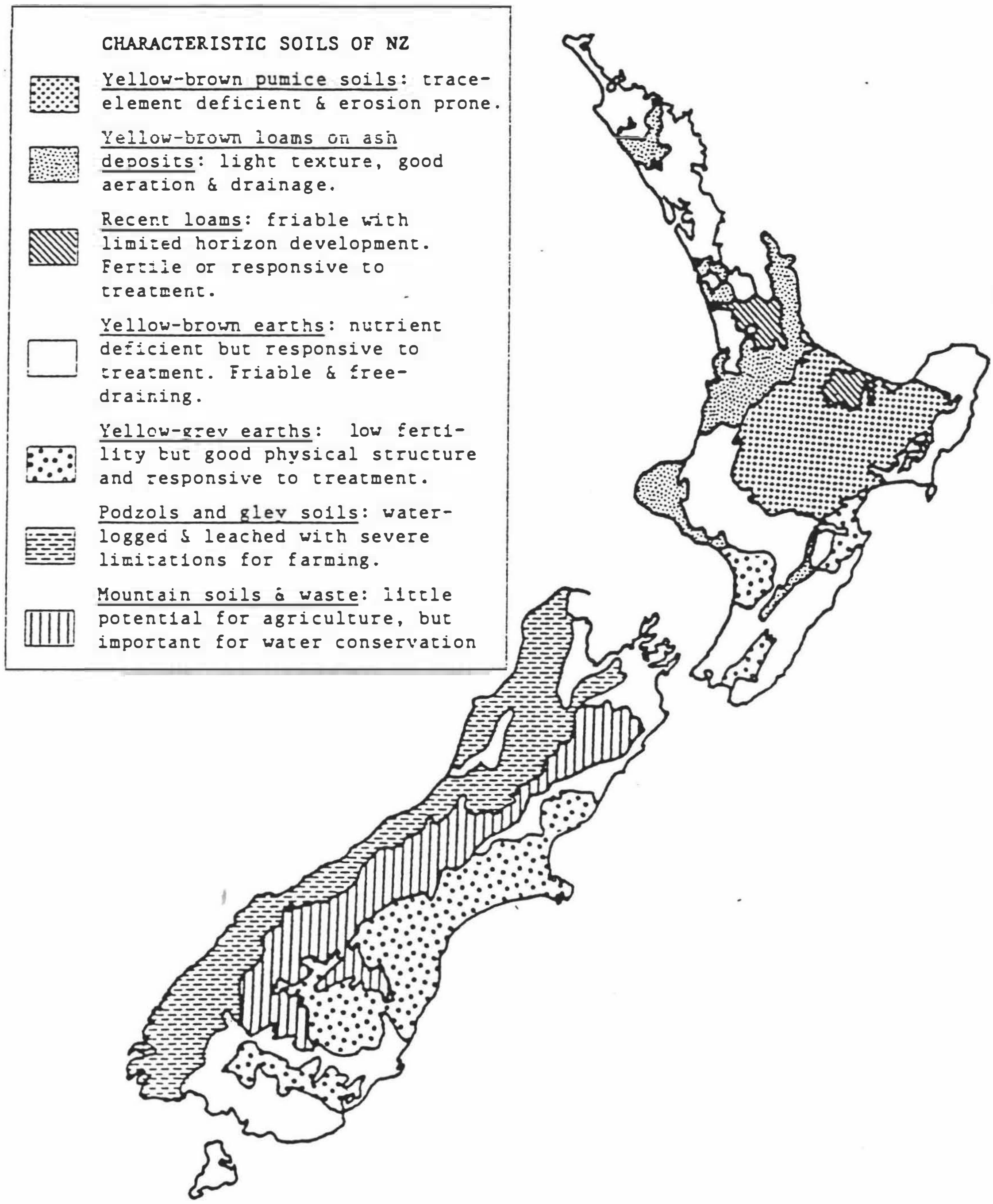

Figure 1A. Spread of dairying in New Zealand in relation to the Charachteristic soils.

Source: Clough *et al.* (1985)

Appendix 2

Summer climate	Winter	Rainfall (mm)	Region
Very warm humid	mild	1100 -1500 and 1500 - 2500	Northland Waikato North Taranaki
Very warm (very sunny)	mild	1000 - 1500	Bay of Plenty
Warm	mild	Evenly distributed 900 -1300	South and Central Taranaki, Rangitikei Manawatu
Very warm dry	moderate	650 - 900	Wairarapa
Warm	cool	650 - 750	Canterbury plains
Warm	cool	evenly distributed 650 - 1250	Southland and Otago Plains
Mild	cool	1500 - 5000	Westland

Table 2A 1. Climate variability in popular dairy regions.

(Source: Radcliffe, 1974a)

Appendix 2A

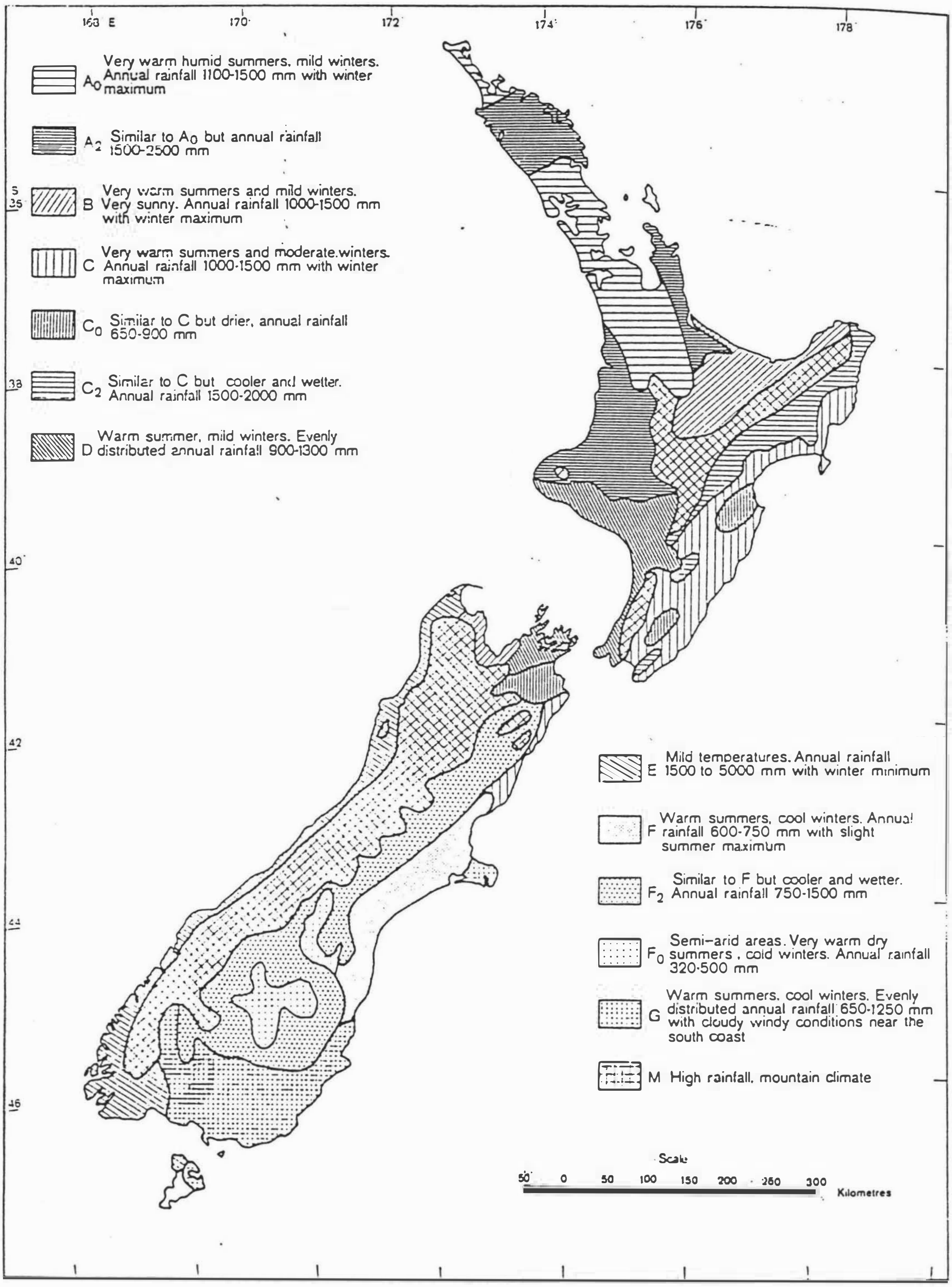

Figure 2A. Climate variation in New Zealand
Source: Radcliffe (1974a)

Appendix 3

Location	soil texture	Ohlsen - P level	Latitude	Altitude	Pasture composition
Warkworth	clay loam	18	36	32	rg/bt/wc*
Te Puke	sandy loam	19	37	28	rg/bt/wc*
Hamilton	clay loams	19	38	40	rg/bt/wc*
Manaia	clay loams	19	39	31	rg/bt/wc*
Wanganui	clay loams	17	39	22	rg/bt/wc*
Gore	clay loam	18	46	76	rg/bt/wc*
Greymouth	clay	16	43	4	rg/bt/wc*

* Perennial ryegrass/brown top/white clover

Table 3A 1. Physical data used to predict PGR from GROW model

Appendix 4

Region	Location	Effective area (ha)	Av. herd size (no.)	stocking rate
Northland	Warkworth	83	170	2.0
Bay of Plenty	Te Puke	78	196	2.5
Waikato	Hamilton	69	189	2.7
South Taranaki	Manaia	70	184	2.6
Central Taranaki	Stratford	66	154	2.3
Rangitikei	Wanganui	100	225	2.3
Manawatu	Palmerston N	102	260	2.5
Wairarapa	Masterton	75	184	2.5
Canterbury (N)	Winchmore	101	217	2.1
Otago	Invermay	101	235	2.3
Southland	Gore	110	224	2.0
Westland	Greymouth	101	178	1.7

Table 4A 1. Regional farm characteristics used for 'Udder' model

Source: Livestock Improvement Corporation, 'Dairy Statistics - 1993/94'

Appendix 5

GROW- Prediction of pasture growth for Palmerston North

Metereological Station	Palmerston North		
Latitude(degrees)	40	Slope	Flat
Altitude(metres)	34	Aspect	Sunny
Distance from coast(km)	45	Pasture type	Rye/white cl/b.top

Month	Temp (C)	Rainfall (mm)	PanET (mm)	AET (mm)
Jul	8.3	33	26	23
Aug	11.1	32	45	38
Sep	11.3	67	69	60
Oct	13.0	93	118	96
Nov	15.5	62	133	111
Dec	16.8	96	149	111
Jan	17.6	7	136	28
Feb	18.8	150	127	88
Mar	15.7	41	142	87
Apr	13.5	45	59	34
May	11.4	110	33	30
Jun	9.9	119	22	20

Fertility (Olsen P) 17

% Species Composition Rye 77 B.top 11 White clover 12

Soil Type Moderate Silt loam

Management 28 day cutting

Print [Y/N]?

Table 5A 1. Validation of GROW model for Massey University's no. 4 dairy farm - 1987/88. Climate and other physical data.

Monthly average growth rates (kgDM/ha/day) for Palmerston North:

Month	Days	Pot	Act	Month	Days	Pot	Act
July	1-15	23	19	January	1-15	20	16
	16-31	24	20		16-31	10	8
August	1-15	43	37	February	1-14	37	29
	16-30	57	51		15-28	58	48
September	1-15	61	58	March	1-15	51	43
	16-30	65	58		16-31	29	24
October	1-15	70	49	April	1-15	32	26
	16-31	76	55		16-31	43	35
November	1-15	73	55	May	1-15	41	33
	16-30	35	26		16-31	36	29
December	1-15	37	29	June	1-15	32	26
	16-31	43	34		16-30	29	23

Total annual production : Potential 15689 kgDM/ha/yr Print [Y/N]?
Actual 12758

Table 5A 2. Validation of GROW model for Massey University's no. 4 dairy farm - 1987/88. Predicted pasture growth rates.

Pasture data - validation of pasture mass using "Udder 7"(No.4 dairy farm - 1987/88)

Date	Farm size ha	Growth kg DM/ha/	Digest DMD%	Cover kg DM/ha	Base kg DM	Density kg DM/cm	MILKER Pregraz kg DM/ha	Allow kg DM/cow	Residual kg DM/ha	Diet Dig DMD%	DRY COW Pregraz kg DM/ha	Allow kg DM/cow	Residual kg DM/ha
01.07	131	22	77	1953	770	240	2378	0	2378	79.8	1870	7.5	773.6
11.07	131	20	77	2006	770	244	2517	0	2517	79.8	2044	8.6	781.9
21.07	137	25	77	2023	770	247	2675	0	2675	79.8	2239	10.5	824.5
01.08	137	32	77	2078	774	250	2898	23.1	1133	80	2600	11.6	910.1
11.08	137	41	77	2427	791	250	3191	25.5	1373	80	3050	15.8	1435.5
21.08	137	50	77	2364	814	251	3523	28.1	1673	79.9	3452	17.9	1821.8
01.09	137	61	76	2324	845	252	3256	31.2	1701	79.9	3256	13	1203.8
11.09	137	66	76	2376	873	254	2955	35.4	1702	79.9	2955	11.8	1029.9
21.09	137	59	75	2461	901	255	3139	37.6	1876	79.6	3139	12.5	1143
01.10	121.4	59	74	2472	930	256	2935	40.4	1833	79.3	2935	13.5	1199.6
11.10	121.4	54	74	2332	958	258	2787	38.4	1691	78.9	2787	15.4	1321.2
21.10	121.4	50	72	2326	986	259	2878	39.6	1781	77.8	1781	0	1781.1
01.11	121.4	45	71	2258	1021	264	2660	36.6	1588	76.8	1588	0	1588.1
11.11	121.4	41	70	2154	1056	271	2660	36.6	1602	75.6	1602	0	1602.2
21.11	121.4	39	70	2016	1092	278	2393	33	1412	75.3	1412	0	1411.8
01.12	121.4	33	69	1892	1152	280	2410	23	1238	74.9	1238	0	1237.7
11.12	121.4	31	69	1817	1220	280	2510	18	1239	74.3	1239	0	1239.4
21.12	121.4	29	69	1785	1289	280	2449	17.6	1302	74.3	1302	0	1301.9
01.01	121.4	25	70	1756	1364	280	2511	14.4	1499	73.5	1499	0	1498.8
11.01	121.4	22	70	1769	1433	280	2254	12.9	1473	71.8	1473	0	1473.4
21.01	121.4	25	69	1806	1477	280	2091	24	1629	73.5	1629	0	1629.5
01.02	121.4	29	69	1842	1417	280	2057	27.1	1774	73.6	1774	0	1774.4
11.02	121.4	34	68	1980	1363	280	2180	28.8	1941	73.6	1941	0	1941.5
21.02	121.4	31	69	2175	1309	280	2360	24.9	2000	74.7	2000	0	2000.1
01.03	121.4	28	70	2293	1267	280	2520	11	1525	73.4	1525	0	1524.7
11.03	121.4	25	71	2229	1214	280	2580	13.9	1644	76.1	1644	0	1644.5
21.03	121.4	26	72	1884	1139	280	2106	11.4	1258	75.2	2106	6.4	1234
01.04	121.4	28	73	1648	1016	280	1800	13.3	1028	76.7	1800	15.9	1262.9
11.04	121.4	30	74	1746	908	279	2107	0	2107	78.8	2107	19.8	1711.1
21.04	121.4	31	74	1872	832	270	2360	0	2360	78.5	2360	22.2	1909.7
01.05	121.4	31	73	1993	770	259	2285	0	2285	78.3	2285	25.8	1723.8
11.05	121.4	30	73	2049	770	237	2426	0	2426	78	2426	27.8	1866.7
21.05	121.4	30	74	2196	770	228	2563	0	2563	78.6	2563	29.4	2001.5
01.06	121.4	29	75	2352	770	231	2697	0	2697	79.2	2697	30.9	2134.4
11.06	121.4	29	75	2531	770	234	2876	0	2876	79.5	2876	16.5	1763.5
21.06	121.4	23	75	2702	770	237	3068	0	3068	79.5	3068	8.8	1266

Farm size	137
Herd size	419
Litres	1480292
Fat	60692
Pasture used (t DM/ha)	9.2
Concentrates fed	0
Fodder 1 fed	108.9
Fodder 2 fed	86.1
Nitrogen	4.5
Conserved	175.1
Crop 1	60
Crop 2	0
Cow potential	1
Part. factor	1

Appendix 6

Appendix 7

Sensitivity analysis: **Warkworth**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.43	0.48	0.51	0.58
	2	0.43	0.48	0.51	0.58
	3	0.43	0.48	0.51	0.58
	4	0.43	0.48	0.51	0.58
	5	0.43	0.48	0.51	0.58
9.00	1	0.37	0.41	0.45	0.52
	2	0.37	0.41	0.45	0.52
	3	0.37	0.41	0.45	0.52
	4	0.37	0.41	0.45	0.52
	5	0.37	0.41	0.45	0.52
10.00	1	0.34	0.38	0.41	0.48
	2	0.34	0.38	0.41	0.48
	3	0.34	0.38	0.41	0.48
	4	0.34	0.38	0.41	0.48
	5	0.34	0.38	0.41	0.48
11.00	1	0.31	0.34	0.38	0.45
	2	0.31	0.34	0.38	0.45
	3	0.31	0.34	0.38	0.45
	4	0.31	0.34	0.38	0.45
	5	0.31	0.34	0.38	0.45

Table 7A 1. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Te Puke**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.29	0.48	0.35	0.40
	2	0.09	0.11	0.13	0.17
	3	0.42	0.46	0.49	0.56
	4	0.26	0.28	0.31	0.37
	5	0.39	0.42	0.45	0.53
9.00	1	0.22	0.25	0.28	0.34
	2	0.02	0.04	0.06	0.11
	3	0.36	0.39	0.43	0.50
	4	0.19	0.22	0.25	0.30
	5	0.32	0.35	0.39	0.46
10.00	1	0.19	0.22	0.25	0.30
	2	0.00	0.01	0.03	0.07
	3	0.32	0.36	0.39	0.46
	4	0.16	0.18	0.21	0.27
	5	0.29	0.32	0.35	0.43
11.00	1	0.15	0.18	0.21	0.27
	2	0.00	0.00	0.00	0.04
	3	0.29	0.32	0.36	0.43
	4	0.12	0.15	0.18	0.23
	5	0.25	0.29	0.32	0.39

Table 7A 2. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Hamilton**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.40	0.44	0.47	0.54
	2	0.24	0.27	0.29	0.35
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
9.00	1	0.33	0.37	0.40	0.47
	2	0.18	0.20	0.23	0.29
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
10.00	1	0.30	0.34	0.40	0.44
	2	0.14	0.17	0.23	0.25
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
11.00	1	0.26	0.30	0.37	0.41
	2	0.11	0.14	0.19	0.22
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00

Table 7A 3. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Manaia**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.18	0.20	0.22	0.27
	2	0.43	0.47	0.51	0.58
	3	0.38	0.42	0.45	0.52
	4	0.17	0.19	0.21	0.26
	5	0.40	0.43	0.47	0.54
9.00	1	0.10	0.13	0.15	0.21
	2	0.37	0.40	0.44	0.51
	3	0.32	0.35	0.38	0.45
	4	0.10	0.12	0.15	0.20
	5	0.33	0.37	0.40	0.47
10.00	1	0.08	0.10	0.12	0.17
	2	0.33	0.37	0.40	0.48
	3	0.28	0.31	0.35	0.42
	4	0.07	0.09	0.11	0.16
	5	0.30	0.33	0.37	0.44
11.00	1	0.04	0.07	0.09	0.14
	2	0.30	0.34	0.37	0.44
	3	0.25	0.28	0.32	0.38
	4	0.03	0.06	0.08	0.13
	5	0.27	0.30	0.34	0.40

Table 7A 4. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Stratford**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.00	0.00	0.00	0.00
	2	0.09	0.11	0.13	0.17
	3	0.27	0.03	0.33	0.39
	4	0.18	0.20	0.22	0.27
	5	0.13	0.15	0.17	0.22
9.00	1	0.00	0.00	0.00	0.00
	2	0.02	0.04	0.06	0.10
	3	0.20	0.23	0.26	0.32
	4	0.11	0.13	0.16	0.21
	5	0.06	0.09	0.11	0.15
10.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.03	0.07
	3	0.17	0.20	0.23	0.29
	4	0.08	0.10	0.12	0.17
	5	0.03	0.05	0.07	0.12
11.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.04
	3	0.18	0.17	0.20	0.25
	4	0.04	0.07	0.09	0.14
	5	0.00	0.02	0.04	0.90

Table 7A 5. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Wanganui**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.22	0.25	0.27	0.33
	2	0.12	0.14	0.16	0.20
	3	0.00	0.00	0.00	0.02
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
9.00	1	0.15	0.18	0.21	0.26
	2	0.05	0.07	0.09	0.14
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
10.00	1	0.12	0.15	0.17	0.23
	2	0.02	0.04	0.06	0.10
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
11.00	1	0.09	0.11	0.14	0.19
	2	0.00	0.00	0.03	0.07
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00

Table 7A 6. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Palmerston North**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.15	0.17	0.20	0.24
	2	0.20	0.22	0.25	0.30
	3	0.00	0.00	0.00	0.02
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
9.00	1	0.08	0.10	0.13	0.17
	2	0.13	0.16	0.18	0.23
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
10.00	1	0.04	0.07	0.10	0.14
	2	0.10	0.12	0.15	0.20
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
11.00	1	0.01	0.04	0.06	0.10
	2	0.06	0.09	0.12	0.17
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00

Table 7A 7. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Masterton**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.27	0.30	0.32	0.38
	2	0.22	0.25	0.28	0.33
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
9.00	1	0.20	0.23	0.26	0.31
	2	0.15	0.18	0.21	0.26
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
10.00	1	0.17	0.20	0.22	0.29
	2	0.12	0.15	0.18	0.23
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00
11.00	1	0.13	0.17	0.19	0.25
	2	0.09	0.11	0.14	0.20
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00

Table 7A 8. Returns to management ($/cow/day) at different economic conditions.

Sensitivity analysis: **Winchmore - irrigated**

Price of bST per treatment $	dose	Price paid for milkfat ($) 5.75	6.00	6.25	6.75
7.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.08	0.10	0.12	0.16
	5	0.31	0.34	0.37	0.43
9.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.01	0.04	0.06	0.10
	5	0.24	0.27	0.30	0.36
10.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.02	0.06
	5	0.21	0.24	0.27	0.33
11.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.03
	5	0.17	0.20	0.24	0.30

Table 7A 9. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Invermay**

Price of bST per treatment $	dose	Price paid for milkfat ($)			
		5.75	6.00	6.25	6.75
7.00	1	0.00	0.00	0.00	0.00
	2	0.09	0.12	0.14	0.18
	3	0.13	0.16	0.18	0.22
	4	0.04	0.06	0.08	0.12
	5	0.22	0.24	0.27	0.32
9.00	1	0.00	0.00	0.00	0.00
	2	0.03	0.05	0.07	0.11
	3	0.07	0.09	0.11	0.16
	4	0.00	0.00	0.01	0.05
	5	0.15	0.18	0.20	0.26
10.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.02	0.04	0.08
	3	0.03	0.06	0.08	0.12
	4	0.00	0.00	0.00	0.02
	5	0.12	0.14	0.17	0.22
11.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.05
	3	0.00	0.02	0.05	0.09
	4	0.00	0.00	0.00	0.00
	5	0.08	0.11	0.14	0.19

Table 7A 10. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Gore**

Price of bST per treatment $	dose	Price paid for milkfat ($) 5.75	6.00	6.25	6.75
7.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.34	0.37	0.41	0.47
	4	0.44	0.47	0.51	0.58
	5	0.71	0.76	0.81	0.91
9.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.27	0.31	0.34	0.40
	4	0.37	0.41	0.44	0.52
	5	0.64	0.70	0.74	0.84
10.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.24	0.27	0.31	0.37
	4	0.34	0.37	0.41	0.48
	5	0.61	0.66	0.71	0.81
11.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.20	0.24	0.27	0.34
	4	0.30	0.34	0.38	0.49
	5	0.58	0.69	0.68	0.77

Table 7A 11. Returns to management ($/cow/day) at different economic conditions.

Appendix 7

Sensitivity analysis: **Greymouth**

Price of bST per treatment $	dose	Price paid for milkfat ($) 5.75	6.00	6.25	6.75
7.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.21	0.24	0.27	0.32
	4	0.29	0.32	0.35	0.40
	5	0.25	0.28	0.30	0.36
9.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.15	0.17	0.20	0.25
	4	0.22	0.25	0.28	0.34
	5	0.18	0.21	0.24	0.29
10.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.11	0.14	0.17	0.22
	4	0.19	0.22	0.25	0.30
	5	0.15	0.18	0.20	0.26
11.00	1	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00
	3	0.08	0.11	0.13	0.18
	4	0.15	0.18	0.21	0.27
	5	0.11	0.14	0.15	0.23

Table 7A 12. Returns to management ($/cow/day) at different economic conditions.