# An *ex post* economic analysis of research and extension for the cover comb.

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# ABSTRACT

Agricultural research funding organisations, such as Wools of New Zealand (WONZ), are seeking ways to maximise benefits from their research portfolio. It has been suggested that this can be achieved by reducing investment in on-farm research and increasing investment in post-farm gate research on processing technology, product development and market research. However, little information exists to substantiate this point-of-view, and this gave rise to the research reported in this thesis. The hypotheses tested were first, that the return on the investment made by Wools of New Zealand in research on cover comb technology was positive and comparable to the return on other investment options, and second, that a model for the *ex ante* economic analysis of on-farm research could be developed using an *ex post* economic analysis of cover comb shearing technology research.

The cover comb is an example of a discrete, relatively simple technology, whose development, research evaluation and extension have been reasonably well documented. Six experiments, funded jointly by Massey University and WONZ, were conducted with the cover comb at Massey University between 1989 and 1995. Most extension costs were incurred by WONZ. The cover comb generates financial advantages to farmers by reducing sheep losses and possibly by conserving pasture when the feed supply is low. Uptake of the cover comb was estimated by surveying shearing contractors and Wool Production Officers, and from the pattern of cover comb sales.

A spreadsheet model was developed to provide an *ex post* cost-benefit analysis of cover comb shearing technology research and extension for the period 1989 to 2020. This model included a sub-model of regional populations by class to estimate the number of sheep shorn by different methods, and a cost-benefit sub-model that described the temporal relationship between costs and benefits and calculated the returns.

The model estimated a 1330% internal rate of return (IRR), a $49.22 million net present value (NPV) and a 115:1 benefit-cost ratio (BCR) for the cover comb research and extension investment at a 5% discount rate. The model outputs were sensitive to the post-shearing reduction in sheep losses associated with cover comb use (and therefore benefits per sheep) and the cover comb adoption rate. A sensitivity analysis indicated a 485% IRR, a $12.30 million NPV and a 25.3:1 BCR at a lower adoption rate (an increase in sheep shorn with a cover comb between 1989 and 2000 due to the research and extension, of 9.5% of all adult sheep in New Zealand, versus an increase of 12.9%), a lower net benefit per sheep ($0.23 per ewe shorn versus $0.47 per ewe shorn) and a 10% discount rate. Thus, even where conservative values for the cover comb technology were applied, a very favourable return on the investment made by WONZ was shown. The rapid uptake of the cover comb (over 30% of ewes shorn were shorn in 1995 with a cover comb, compared to 15% of ewes in 1989), and the size of the industry (33.7 million ewes in 1995) the technology is applied to contributed to these returns.

The *ex post* cost-benefit analysis model could be adapted for *ex ante* evaluations of proposed on-farm wool industry research. This model would be useful for deciding which sheep production research should be funded.

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# CHAPTER ONE

# INTRODUCTION

In this chapter a context is provided for the study of costs and benefits associated with the research and extension of cover comb shearing technology. The literature is reviewed with respect to the methods for research evaluation, factors affecting technology uptake, the development of cover comb technology and its applications, and the purpose and role of modelling. The concluding section to the Chapter outlines the purpose and scope of the study.

## EVALUATION OF RESEARCH

### Background

Research is evaluated in order to optimise the use of research funding and to justify continued investment in research. *Ex ante* studies optimise the use of research funding by prioritising between research projects. *Ex post* studies use historical data to determine returns from past research, to justify continued research investment.

Horton *et al.* (1993) define research evaluation as "judging, appraising, or determining the worth, value, or quality of research, whether it is proposed, on-going, or completed. This is done in terms of its relevance, effectiveness, efficiency, and impact. *Relevance* refers to the appropriateness of goals and objectives in relation to assessed needs. *Effectiveness* refers to the degree to which goals have been achieved. *Efficiency* refers to the cost-effectiveness of activities. And *impact* refers to the broad, long-term effects of research."

Governments, donor agencies, tax-payers and farming organisations are questioning the value of past and continued investment in agricultural research (Marsden *et al.*, 1980; Bezar, 1993; Horton *et al.*, 1993). Governments, research and research-funding organisations, and private businesses are asking what the returns from future agricultural research are likely to be (Norton and Davis, 1981; Contant and Bottomley, 1988; Bezar, 1993; MoRST, 1996). Agricultural research is seen as a long-term, high risk investment (Bezar, 1993). Government expenditure in agricultural research in New Zealand has declined in recent years due to changes in priorities and a shift to greater private sector funding (Ulyatt, 1986; Bezar, 1993). The strategy developed by the Science and Technology Expert Persons Panel in 1992 suggested expenditure on agricultural production research be reduced further, while investment in research on food processing or added value activities should increase (Bezar, 1993).

A number of arguments have been put forward for a reducing agricultural production research. One case is that New Zealand's agricultural exports now account for a lower proportion of total exports by value: from 80% to 90% in the 1960's, to 50% to 60% in the 1990's (Reid, 1996). In addition, the rate of growth in New Zealand's agricultural industry has slowed since the 1960's: most of this has been as a result of factors outside the control of the agricultural industry (Ulyatt, 1986; Reid, 1996). Another case, challenged by Scobie *et al.* (1991), is that substantial gains in agricultural production efficiency have already been made and it can be questioned whether further production research would have a significant on-farm impact. Agricultural production research can have a ten to fifteen year lag before results are utilised. In comparison, the return to investment in product development and technology transfer can be quicker and more certain than production research (Ulyatt, 1986). It has been incorrectly assumed that farmers' share of total benefits of new technology will be the same whether technology is introduced at farm or processing levels: returns to producers from production research are greater than those from processing research (Scobie *et al.*, 1991).

Research is evaluated at various levels (e.g. programme, project, portfolio, output class and national level of investment). Different types of information are required by decision makers at each level (Horton *et al.*, 1993; MoRST, 1996). This information is used for research priority setting, which is both a "bottom up" and "top down" process. Major priorities are set at the "top", or ministerial level, in the case of public-funded research. Farmers' perspectives also need to be considered in setting agricultural research priorities, because to be effective, research should generate technologies useful for farmers (Contant and Bottomley, 1988; Horton *et al*., 1993; Reid, 1996). Input into decisions on research priorities requires feedback from many sources. These may include farmers, extension officers, scientists, managers and economists. Both quantitative and qualitative data need to be considered when determining what funds should be allocated to particular strategies or individual projects.

Private research usually involves some sort of formalised evaluation procedure (Horton *et al*., 1993), with research priorities being strongly influenced by market forces (Contant and Bottomley, 1988). In contrast, publicly funded research also often has goals and objectives which are non-economic. MoRST (1996), in discussing the selection and implementation of methodologies for the evaluation of the Public Good Science Fund (PGSF) listed eighteen strategic goals and key factors for priority setting. These included science, economic, environmental and social goals. This diversity of goals makes evaluation of research priorities more difficult. Formal evaluation of research has often been limited in the past, and in many areas is still in the process of development (Contant and Bottomley, 1988; Horton *et al*., 1993; MoRST, 1996).

Past research evaluation has often been carried out to meet accountability requirements to donor agencies or farmers groups, or by donor agencies to demonstrate the economic impact of agricultural research. In other organisations, research evaluation and monitoring has tended to be informal and of little use for decision making as to how scarce funds should be allocated (Horton *et al*., 1993).

Methods for evaluation of research, and research priority setting range from simple checklists or scoring methods (Contant and Bottomley, 1988; Horton *et al*., 1993) through to more complicated economic analyses (Norton and Davis, 1981). The more commonly used methods are discussed in the next section.

**Types of Evaluation Used**

Contant and Bottomley (1988) outlined seven methodologies which can be used to establish research priorities. These were congruence, checklists, scoring, domestic resource cost ratios, cost-benefit analysis, mathematical programming, systems analysis and simulation analysis. Econometric methods are also used for *ex post* economic evaluation of research (Norton and Davis, 1981; Falconi, 1993; MoRST, 1996). Other methods used for setting research priorities include precedence, models of regional spillover effects and optimal growth models (Fox, 1987), indicators, opinion surveys, peer review and bibliometrics (Ballantyne and Uribe, 1993; Gapasin and Uribe, 1993; Horton *et al.*, 1993; Buwalda *et al.*, 1996; MoRST, 1996). A combination of these methods is sometimes used.

The various methods used for the evaluation of research are described in Bell (1976), Norton and Davis (1981), Fox (1987), Contant and Bottomley (1988), Arnon (1989), Echevarria (1990), Ballantyne and Uribe (1993), Falconi (1993), Gapasin and Uribe (1993), Norton (1993), Uribe and Horton (1993), Buwalda *et al.* (1996) and MoRST (1996). The more commonly used methods are briefly described below.

Congruence methods allocate research funds to commodities in the same proportion as their existing contribution to the agricultural domestic product. Precedence allocates resources at the same proportion as past allocations. The weakness with these methods is that well-established commodities are favoured over new ones or those with a low current value (Fox, 1987; Contant and Bottomley, 1988).

Checklists are sets of questions that need to be answered during the evaluation process (Uribe and Horton, 1993). Scoring models are an adaptation of the checklist method, in which the checklist criteria are weighted. Scoring methods have been used widely as a method of research evaluation, sometimes in association with quantitative or economic evaluation. A description of scoring methods for research evaluation can be found in Norton and Davis (1981), Fox (1987), Contant and Bottomley (1988), Norton (1993), and MoRST (1996). These methods can provide a good basis for research evaluation, are useful where non-economic objectives are included, and are easily applied. They do, however, tend to be subjective (both in deciding the criteria and weightings), lack flexibility and rely heavily on statistical information (MoRST, 1996).

Peer review involves the evaluation of research activities, proposals, programmes and products by specialists working in the same or related fields. This is a relatively simple approach which focuses on the scientific merit of research. Its limitations are that it is subjective and limited to a narrow field (Gapasin and Uribe, 1993; Buwalda *et al.*, 1996).

Qualitative indicators are often applied where research outcomes are not able to be measured directly. Indicators that have been used include: farm-level adoption rates; changes in yields or prices; numbers of scientists, engineers, technicians or extension workers in the work force; number of research contracts; number of patents; publication counts and citations (Horton *et al.*, 1993; Buwalda *et al.*, 1996; MoRST, 1996).

The econometric and the economic surplus methods are the most widely used economic methods employed in the evaluation of research. The econometric approach (production, profit and supply functions) treats research as a variable. A marginal rate of return as well as an average rate of return is calculated with this method. This method is generally used for *ex post* research evaluation at an aggregate level. The economic surplus approach (consumer-producer surplus, index number method and cost-benefit analysis) measures the change in consumer and producer surplus from a shift to the right in the supply curve due to technological change (Echeverria, 1990). Cost-benefit analysis is discussed in more depth later. Where research objectives are not only economic, other methods of evaluation should be used as well. Economic methods have been reported widely in the literature. Some background on the use of these methods for research evaluation can be found in Norton and Davis (1981), Fox (1987), Echeverria (1990), Falconi (1993), Buwalda *et al.* (1996), and MoRST, 1996.

In simulation models, mathematical relationships among the variables are exposed to different scenarios to assess the best outcome. These can include many factors such as multiple goals, research constraints, socio-economic variables, risk and uncertainty (Falconi, 1993). Mathematical programming identifies an optimal research portfolio based on multiple goals and resource constraints such as funding, human capital, environmental factors and technology (Falconi, 1993). The characteristics of these two approaches were earlier summarised by Norton and Davis (1981). Systems analysis and mathematical programming are unlikely to be widely used because of their high levels of sophistication, data needs and skill requirements (Contant and Bottomley, 1988).

**Practicalities of Research Evaluation**

Research evaluation is conducted by private and public research funding organisations. Public investment in research, as previously mentioned, can have non-economic objectives as well as economic objectives. The focus of this discussion is more on public rather than private investment in research, although many of the issues apply to both types of investment.

It is not possible to have a single evaluation methodology for the whole of public investment in science because of the non-homogenous nature of research investment alternatives (Buwalda *et al.*, 1996). MoRST (1996) identified the critical characteristics required for an evaluation framework for the Public Good Science Fund (PGSF), as being: the use of a cost-benefit paradigm for comparing with alternative investments; a clear distinction between results attributable to PGSF investment and associated private investment; a set of criteria able to be applied consistently to a varied range of outputs over time; ability to provide a marginal cost benefit; ability to diagnose barriers to achieving maximum effectiveness for correction, and ability to recognise the long term nature of research outputs.

In research evaluation, both qualitative and quantitative aspects need to be considered. Questions should be asked regarding the relevance of the research objectives, and whether these were attained (*ex post*), the contribution to knowledge, the availability of research resources, and the appropriateness of public funding. Research costs, the duration of the research, the likely success of the research, associated on-farm costs, the benefits, research and adoption lags, the adoption rate, the ceiling level of adoption, and research depreciation all need to be identified, particularly if a cost-benefit analysis is involved. Other factors that may need to be considered are likely spillover effects, equity issues, extension required and associated costs, associated private investment in research, taxation dead-weight loss, attribution of research outcomes, indirect costs and benefits, and potential areas for further research. These points have been discussed in Miller (1982), Contant and Bottomley (1988), Harvey (1988), Dillon and Anderson (1990), Anderson and Herdt (1990), Echeverria (1990), Horton (1990), Horton *et al.* (1993), Buwalda *et al.* (1996) and MoRST (1996).

The optimal level of research and development investment can be defined as the level beyond which marginal costs exceed marginal benefits. It has been argued that research provides increasing rather than diminishing returns, in which case the optimum would occur when marginal costs increase faster than marginal benefits (Harvey, 1988). These increasing marginal benefits occur because research in one area can benefit a different sector, benefits can be cumulative over time, and benefits such as enhanced human capital are difficult to measure (Harvey, 1988; MoRST, 1996). Harvey (1988) argued that the law of diminishing returns assumes that resources are limited, whereas the objective of research is to increase the capability of available resources thus denying the basic premise of the law.

Research benefits were described by Miller (1982) as commensurable, incommensurable and intangible. Commensurable benefits are those that directly measure increased efficiency of output. Incommensurable benefits are measurable side benefits. These may be measured in economic or physical terms, and are not necessarily additive to commensurable benefits. Intangible benefits can be described but not measured. Only commensurable benefits are measured in an economic evaluation such as cost-benefit analysis, but as outlined earlier incommensurable and intangible benefits also need to be considered in research evaluation. The terms can also be applied to research costs (Miller, 1982).

There are limitations in the methods used for the evaluation of agricultural research. These limitations can apply generally or be method-specific. Some of the difficulties associated with research evaluation, the strengths and weaknesses of the various methods, and issues that may need consideration in research evaluation are discussed in Marsden *et al.* (1980), Norton and Davis (1981), Fox (1985), Davis *et al.* (1987), Fox (1987), Contant and Bottomley (1988), Dillon and Anderson (1990), Harvey (1988), Anderson and Herdt (1990), Echeverria (1990), Horton (1990), Chavas and Cox (1992), Anderson and Hardaker (1992), Horton *et al.* (1993) and MoRST (1996). Some of these issues are outlined below. Those relating to cost-benefit analysis will be covered in more detail in the next section. A number of case studies in the textbook "Methods for diagnosing research system constraints and assessing the impact of agricultural research" describe how some of these issues have been allowed for (Echeverria, 1990).

Identification and quantification of the variables associated with the research can be difficult, particularly *ex ante* or where inputs and outputs may be of more than one dimension (Dillon and Anderson, 1990; Anderson and Hardaker, 1992). The likelihood of success has to considered against the potential returns from the different research proposals (Contant and Bottomley, 1988; Anderson and Hardaker, 1992). There is also uncertainty in predicting prices and adoption rates, particularly *ex ante* (Contant and Bottomley, 1988). The research and adoption lag lengths can affect the research returns: the shorter the lag, the greater the return (Contant and Bottomley, 1988).

Difficulties can occur in defining where the research being evaluated starts and ends. Spillover effects can occur between the different research areas (Anderson and Herdt, 1990; MoRST, 1996) and across international boundaries (Davis *et al.*, 1987; Alston and Mullen, 1992) although some adaptive research may be required in order to capture these benefits. The contribution made by private research also needs to be considered (Pray and Neumeyer, 1990). Therefore, in attributing research benefits it is necessary to identify how much is due to the study in question, and how much is due to other research efforts.

It can be difficult to attribute benefits and costs to a specific study or research area. Research is often built on other research, with applied research likely to be based on results of basic research (Arnon, 1989; Bezar, 1993; Ralph, 1993). Basic research is generally unable to be evaluated with economic analysis because of the uncertainty about outcomes: peer assessment or scoring methods may be more appropriate even though they can be subjective.

The comparison of different types of research programmes with diverse objectives is difficult, and formal priority setting techniques have varying degrees of applicability (Contant and Bottomley, 1988; MoRST, 1996). Social, environmental and political objectives (e.g. equity or environmental issues) may have a value different to that indicated by monetary terms, or may not be able to be valued economically easily if at all; the quantification of these will involve attempting to put a fair value or weighting on these objectives (Contant and Bottomley, 1988; MoRST, 1996). The question also arises as to who should be paying for research, and attempts have been made to measured those who benefit in order to attribute costs more fairly (Harvey, 1988; Alston and Mullen, 1992). However secondary spin-offs, which may not be measured, will often benefit other segments of the community e.g. poorer farmers may benefit later (Dillon and Anderson, 1990). There are often also nutritional and health spin-offs from agricultural research (Harvey, 1988; Arnon, 1989).

Research has an element of serendipity, and there is concern that “over management” of research could adversely affect this (Norton and Davis, 1981). Political pressure may allow some projects high priority against scientific advice (Contant and Bottomley, 1988). The nature of research is such that some degree of long term stability is required in allocating funds to projects (Contant and Bottomley, 1988; MoRST, 1996).

All costs need to be included in an economic evaluation, therefore overhead costs will have to be allocated to the research (Marsden *et al.*, 1980; Contant and Bottomley, 1988). Fox (1985) argued that the taxation dead-weight should also be included for public research: Stuart (1984), for example, estimated 20 to 50 cents deadloss per dollar of tax collected at the margin in the USA. The technology uptake is less likely to be as rapid without associated extension, so these costs should be included, or benefits allocated accordingly (Marsden *et al.*, 1980).

A criticism of some past research evaluations is that only the successful research has been considered, and this has resulted in high estimated returns (Marsden *et al.*, 1980). In an economic evaluation all research costs can be included against the returns from the more successful trials to counteract this; this in turn will lead to underestimated returns. Past studies have shown that the high returns from a few successful innovations can compensate for research which has little or no return, justifying past investment in research (Marsden *et al.*, 1980; FoRST, 1997). Harvey (1988) argued that a certain level of research is necessary to maintain current productivity e.g. research into disease resistance. The assumption is usually made that the base level of productivity is zero in the absence of research, when in reality it could be negative, resulting in underestimated research returns.

Research evaluation has benefits other than priority setting or evaluating past research. Greater long term stability in research (which is necessary due to its long term nature) can be achieved by more effective planning (Horton *et al.*, 1993). The information gathering process is useful in itself, requiring managers and researchers to think through the factors contributing to research and development, and to identify areas of concern and potential areas for future research, and can assist in implementing research results and resource planning (Marsden *et al.*, 1980; Bennett, 1993; Bezar, 1993). Closer collaboration by researchers, extension workers, economists would also be encouraged. If researchers adopt the cost-benefit approach, communication with the business world may also be more effective and productive (Bezar, 1993).

**Cost-Benefit Analysis**

Cost-benefit analysis is based on the concept of discounted cash flow: the premise that a dollar earned today is worth less than a dollar earned in the future, because of its interest-earning potential lost in the meantime. In research evaluation, the time-valued costs of the research are compared against the time-valued benefits of the research (Contant and Bottomley, 1988). Variables which have to be defined in cost-benefit analysis have been outlined in the previous section. Measures used in cost-benefit analysis, as defined by Gittinger (1982) include:

$$\text{Net Present Value (NPV)} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t}$$

$$\text{Internal Rate of Return (IRR)} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0$$

$$\text{Benefit-Cost Ratio (BCR)} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}}$$

where: $B_t$ = benefit in each year

$C_t$ = cost in each year

$t = 1,2,3,....n$

$n$ = number of years

$i$ = interest or discount rate

In using cost-benefit analysis for selecting the projects to be undertaken, all those with a NPV greater than or equal to 0, a BCR greater than or equal to 1, or an IRR greater than the target interest rate should be undertaken. In choosing between mutually exclusive projects, the one with the greatest NPV should be chosen. The BCR and the IRR criteria cannot be use to choose between mutually exclusive projects. These methods cannot be used to rank projects if there are short term budget constraints. Perkins (1994) provides a good summary of the merits and applicability of different discount measures.

Cost-benefit analysis is based on the concept of economic surplus. The benefits of research are represented by a shift to the right of the upward sloping supply curve, providing benefits to both producers and consumers. The distribution of benefits depends on the elasticities of the supply and demand curves, and the magnitude and nature of the supply shift. Cost-benefit analysis sometimes assumes linear supply and demand curves, with a parallel shift of the supply curve, oversimplifying the situation. The economic-surplus approach (which includes cost-benefit analysis) is a partial equilibrium approach, evaluating only the one market affected directly by the research, and ignoring secondary effects due to changes in other markets which can increase income gains (Marsden *et al.*, 1980; Dillon and Anderson, 1990).

The elasticity's of the supply and demand curves affect the distribution of benefits between producers and consumers. The more inelastic the demand, the more likely it is that producers will lose following technical change. If supply elasticity is greater than demand elasticity, consumers receive a larger share of the benefits (Norton and Davis, 1981). The nature of the supply shift (which can be parallel, convergent or divergent) will have an effect on the distribution of benefits between marginal and infra-marginal producers (Marsden *et al.*, 1980). Large-scale farmers are more likely to benefit from convergent shifts. Research benefits may also be due to a shift to the left in the demand curve, as in increased quality rather than increased output (Dillon and Anderson, 1990).

Costs and prices used in an economic cost-benefit analysis reflect the opportunity cost of a good or service; that is "the benefit foregone by using a scarce resource for one purpose instead of for its next best alternative use" (Gittinger, 1982). In a free market economy, it is usually assumed that widely traded goods will be in their most productive use, therefore market price is the best estimate of opportunity cost. Shadow prices are used where the market price is believed to be a poor estimate of economic value (Gittinger, 1982). Distortions in market prices can occur due to government intervention (taxes, tariffs and subsidies, price and wage controls, intervention in foreign exchange and financial markets), monopolies, and unemployment or use of family labour. Shadow prices can be calculated for externalities and public goods, reflecting their cost or benefit to society. Weightings can be allocated to give higher priority to projects benefiting one sector of the community over another. These concepts, and the various techniques used to derive these shadow costs and prices, and weightings, have been widely discussed in the literature.

General principles applying to cost-benefit analysis are discussed in more depth in Squire and van der Tak (1975), Sugden and Williams (1978), Gittinger (1982), Mishan (1988), Gramlich (1990), Layard and Glaister (1994), Perkins (1994) and Zerbe and Dively (1994). Issues relating to cost-benefit analysis for research evaluation are discussed in more detail in Marsden *et al.* (1980), Norton and Davis (1981), Meister (1985), Contant and Bottomley (1988), Dillon and Anderson (1990), Echeverria (1990) and Bennet (1993).

The appropriate discount rate to use is another consideration in cost-benefit analysis (Marsden *et al.*, 1980; Meister, 1985). Cost-benefit studies sometimes use a range of discount rates to test the sensitivity of the result to discount rate (Dick *et al.*, 1967; Marsden *et al.*, 1980; Bezar, 1993).

Meister (1985) suggested that cost-benefit analysis can be misused by manipulating assumptions, weightings and data in order to obtain the desired results. Thus, it is necessary to retain the simplicity of cost-benefit analysis to preserve its strength of openness and transparency. It is a useful guide for comparing policies but does not provide precise answers.

Advantages of cost-benefit analysis for research evaluation include: its ability to provide an objective means of comparing a wide and varied range of research investments; it is readily understood; it can be used for *ex post* and *ex ante* evaluation;

distributional effects can be considered; it can be conducted at different levels; secondary impacts can be included if they are identifiable and measurable; and it can increase the explicitness of government decision-making and provide a check on the actions of government, by including those affected by a decision in the collection and availability of information (Norton and Davis, 1981; Bennett, 1993). Sensitivity analysis can be used to determine possible investment returns from different probabilities of success, yield increases, price changes, time lags and adoption rates (Bennett, 1993).

**Past Returns to Agricultural Research Investment**

There have been a number of studies over the years to estimate the returns to investment in agricultural research at the aggregate, commodity and project level. Echeverria (1990) summarised the returns to investment in agricultural research for 128 studies from 1958 to 1990. Results suggest the return to the research and extension has almost without exception been highly profitable, with internal rates of return ranging from -38% to 440%. The majority of returns were positive (only one was negative), and between 20% and 50%.

There have been some recent studies on returns to investment in research in the Australian agricultural industry. Scobie *et al.* (1991) found the return to investment in research on Australian wool production to be 9.5% to the Australian wool industry and 25% to the Australian woolgrower. Alston and Mullen (1992) calculated 58% of the benefits from Australian wool industry farm-level research accrue to Australia and the remainder to the rest of the world. Mullen and Cox (1995) found the return to investment in Australian broadacre research (with a 16 year lag profile) to be 30% for the period 1968 and 1988, and 24% for 1953 to 1988. The return dropped to 17% with a lag profile of 34 years in the 1953 to 1988 period. Estimates of the internal rate of return for extension were 40% and 45% for the 16 and 35 year profiles, respectively. Australia's share of broadacre research returns was predicted to be about 75%. Voon and Edwards (1992) estimated that Australia had the potential to obtain net benefits of A$53 million per year, from a one percentage increase in protein content in wheat; over 93% of this benefit would be to wheat producers. Thus, research in this area has the potential to generate high returns.

The Commonwealth Scientific and Industrial Research Organisation (CSIRO) has conducted cost-benefit analysis studies on the return to investment in research. A 1980 study of the CSIRO's Entomology Division estimated the returns on 13 of the division's more successful projects (Marsden *et al.*, 1980). Benefits accruing in the period 1960 to 2000, from research undertaken between 1960 and 1975, were measured. Total divisional costs were allocated to these 13 projects based on the number of staff involved. The return to research was therefore underestimated, however the costs of basic research and unsuccessful research were included in the returns. The internal rate of return for the overall research was 19%. The net present values (1975) ranged from A$0.1 to A$261.2 million. Results demonstrated that the majority of research projects have low direct economic benefits, but one or two successes can pay for the activities of a research agency for a decade or more (Marsden *et al.*, 1980). Ralph (1993) reported on a CSIRO Plant Protection and Processing Institute study focusing on 10 well-documented projects with clear market outcomes. Costs were allocated based on the number of researchers involved in the projects. A 40 year time span was allowed for the benefits to accrue, and a 5% discount rate was assumed. The overall benefit:cost ratio was 14:1 (ranging from 0.8:1 to 29.6:1 for the individual projects).

Some other overseas studies in which returns to agricultural research investment have been calculated include: Norton *et al.* (1987) who derived a 17% to 35% internal rate of return on aggregate agricultural research and extension of five commodities in Peru; Norgaard (1988) who calculated a benefit:cost ratio of 149:1 at a discount rate of 10% for biological control of cassava mealybug in Africa; Traxler and Byerlee (1992) who estimated rates of return to crop management research between 11% and 23%; and Chavas and Cox (1992) who estimated returns of 28% and 17% for public and private research, respectively.

The first well-known New Zealand study of research returns was that of Dick *et al.* (1967). A cost-benefit analysis was conducted on returns to research and extension of research into artificial breeding of dairy cattle, diffusion impregnation of timber, leather research, and weedkiller development. Overall returns to agricultural research and related extension by the then Departments of Agriculture, and Scientific and Industrial Research was also estimated. The internal rates of return calculated for the four examples ranged from 10% to 20%. Sensitivity analyses were conducted for different technology uptakes. The overall return to research was estimated at 19%. Scobie and Eveleens (1986) used an econometric model to predict a 30% return to investment in agricultural research in New Zealand from 1926/27 to 1983/84 using a lag length of 23 years as the best estimate. Estimates were also made for lag periods of 8, 16 and 29 years with rates of return of 66%, 39% and 15%, respectively. Scobie and St-Pierre (1986) estimated the return on further research to identify the "true" value of the residual phosphate effect (proportion of available phosphate in the last period which is transferred to the current period) to be 37.2%. This knowledge would enable more accurate fertiliser recommendations to be made, with a small increase in returns per hectare; the high research return being largely due to the size of the industry. In a more recent cost-benefit analysis on the return to research in breeding programmes for bread wheat, Bezar (1993) calculated an internal rate of return of 64%.

FoRST (1997) has just completed a study of the benefits of meat research, evaluating seventeen meat industry technologies, although a cost-benefit analysis was only able to be completed for five of these. The internal rates of returns were 7%, -51%, 33%, 110% and -40% for accelerated conditioning and ageing, Aujeszky's disease eradication programme, the loin boner, MIRINZ low temperature rendering system and Phenax (first antibiotic-free vaccine manufactured in NZ, in this case for scabby mouth), respectively.

These studies show the majority of returns to agricultural research in the past have been positive, with most estimates in the 20% to 50% range. These returns compare very favourably with returns from alternative investments (Dick *et al.*, 1964; Marsden *et al.*, 1980; Norton *et al.*, 1987; Ralph, 1993). However, these findings are not supported by Fox (1985), and Mullen and Cox (1995) who argue that there is no evidence to support either under- or over-investment in agricultural research.

## RESEARCH IMPACT AND TECHNOLOGY UPTAKE

The impact a research programme has is dependent on the research cost, duration and probability of success, the size of the benefits, the uptake, and the depreciation of the results. Since discounted present values are used to measure the benefits and costs, the time lag between the research expenditure and final adoption is important (Davis *et al*., 1987). Hastings (1981) defined three time lags: the lag between research expenditure and research output; the lag between these discoveries and their use; and the lag incorporating the depreciation of that discovery. It is difficult to disassociate these lags, and they are often incorporated into one. Davis *et al*. (1987) estimated the average lag, based on previous research, to be eight years for the completion of research with a further three years required for the adoption of a new technology. Lags in livestock industries tend to be higher (Scobie *et al*., 1991). Scobie and Eveleens (1986), in measuring the return to agricultural research and extension in New Zealand using a production function approach, found the lag length with the best fit to be 23 years, with a peak marginal return after 11 years.

### Research Aspects

Research-related aspects of impact and uptake are the cost and duration of the research, and the probability of success (Contant and Bottomley, 1988). The cost and duration of the research are likely to be dependent on the type of research (Anderson and Hardaker, 1992).

The probability of success may be dependent on a number of factors. These include the type of research; the current stock of knowledge; the record, age, position and status of the research team; the institutional structure; and the outcome of related complementary and competitive projects (Harvey, 1988). Some types of research have a high risk of failure or are of long duration but are likely to have a large impact if they succeed (e.g. vaccine development); others are more predictable, and the returns are more dependent on uptake (e.g. plant breeding) (Contant and Bottomley, 1988). The chance of research success may also be greater in the early stages of research in a particular scientific field, than in the later stages (Harvey, 1988).

In research evaluation, the uncertainty of a successful result can be dealt with by sensitivity analysis, conservative estimates (Contant and Bottomley, 1988) and multiplying expected benefits by the chance of success (Davis *et al.*, 1987; Bezar, 1993).

**Technology Uptake**

The return to research is affected by the extent and rate of adoption (Marsden *et al.*, 1980; Davis *et al.*, 1987; Contant and Bottomley, 1988). A reasonably accurate estimate of these is essential; a 10% reduction in the adoption rate, or a delay of three years in research completion, may reduce returns by considerably more than a substantial increase in research costs (Contant and Bottomley, 1988).

Factors other than research investment can influence the adoption of a technology. These can include the level of farmer education, availability of communication facilities and other infrastructural support services, extension services, sales programmes, terms of trade, and weather (Dillon and Anderson, 1990; Mullen and Cox, 1995). Other factors, some of which may be of more importance in less developed countries, can include the availability of credit, markets, inputs, pricing policies, and land tenure arrangements (Norton *et al.*, 1987; Arnon, 1989).

Rogers (1983) defined diffusion as " the process by which an *innovation* is *communicated* through certain *channels* over *time* among the members of a *social system*". The adoption of a technology is affected by these elements.

An S-shaped curve is used to describe the rate of adoption over time, with "innovativeness" categories being applied to adopters to describe the uptake (Rogers, 1983). This S-shaped diffusion curve takes off at 10% to 25% adoption. Innovators are the first 2.5% to adopt an innovation: they are believed to be well informed, cosmopolitan, adventurous and have reasonable financial resources. The next 12.5% are referred to as early adopters; they are well integrated into local society, with a greater number of opinion leaders than in the innovators group. The early majority are next (34%), followed by the late majority (34%), then the laggards (16%), getting progressively more conservative (Scrimgeour *et al.*, 1991). These categories have since been questioned, with suggestions that the non-adoption of a technology is due to a deliberate decision not to adopt (Guerin and Guerin, 1994) or an inability to adopt due to lack of resources or finances (Arnon, 1989; Reid *et al.*, 1996) rather than conservatism.

Communication channels can be via mass media or interpersonal (Rogers, 1983; Scrimgeour *et al.*, 1991). Mass media are important initially to spread information about a new technology; interpersonal communication is more important at the persuasion stage. Interpersonal communication can be through opinion leaders (individuals who influence the opinions of others in informal ways) and change agents (who act as communication links between two or more social systems) (Scrimgeour *et al.*, 1991).

The traditional transfer of research technology model has been a "top down" approach with information flowing from scientists and extension agents down to farmers (innovators down to laggards) (Reid, 1996). More recent approaches involve farmers being more actively involved in research and extension, making this a two-way process e.g. participatory action research, farming systems research (Guerin and Guerin, 1994; Reid, 1996).

The important characteristics of the innovation were described by Rogers (1993) as: relative advantage (the degree to which it is better than the idea it supersedes); compatibility (consistency with existing values, past experiences and needs); complexity (difficulty to understand or use); trialability (degree to which it can be experimented with on a trial basis); and observability (visibility of results to receivers and others). Reid *et al.* (1996) conducted a study of dairy farmers, to evaluate the use of these attributes in explaining the adoption and use of technologies by dairy farmers. Trialability, complexity, compatibility and relative advantage were all perceived by the case farmers as being important. Other factors identified by the farmers as being important in the decision to adopt a technology were risk and flexibility. Technologies that were able to used as or when required, and technologies that allowed greater "peace of mind", were regarded favourably. Decisions to adopt a technology were influenced by the farmer's circumstances at the time.

Before research results can be applied, development and commercialisation of the results may be necessary (Rogers, 1983). Unavailability of necessary inputs may slow or delay the uptake of a technology. This occurred in the USA with no-till farming, which was researched in the 1950s, but the necessary technology was not available commercially to farmers till the late 1960s (Rogers, 1983). Consequently, Johnson *et al.* (1992), cited by Bezar (1993), concluded that "the largest economic benefits are frequently associated with research that yields simple technologies that are quickly adopted and widely applicable and lead to significant cost reductions in the industry. A low and slow adoption rate can greatly reduce economic benefits."

Arnon (1989) cautioned that the assumption "...the adoption of a technology by farmers must be a basic measure of research effectiveness" is misleading, and is only justified where research results are not applicable, or costs of a technology exceed benefits. Excellent results may fail to be adopted because of factors beyond the control of the research, as illustrated by Rogers' (1983) innovation model. This is also supported by Harvey (1988) who noted that not all results can be expected to be adopted, but that many of these results provide opportunities to adapt to circumstances in the future.

## Size of the Industry

The size of the industry to which the research results apply will have a greater impact on returns to the research than the likelihood of success, the magnitude of the benefits, or the extent and rate of adoption (Marsden *et al*., 1980). A high risk venture applicable to a large industry (e.g. sheep) will have a higher expected pay-off than a more certain project applicable to a smaller industry (e.g. poultry) in New Zealand or Australia, for example.

## Research Depreciation

Research depreciation is based on the premise that new knowledge cannot be destroyed, but can be rendered obsolete by additional knowledge (Harvey, 1988). It can be made redundant by demand patterns and resource supply conditions, and can be partly influenced by research and development. The output improving effects of an innovation may not last e.g. disease resistance, irrigation may in turn cause salinity decreasing yields eventually. Research depreciation will have an effect on the return to research (Contant and Bottomley, 1988), and this is incorporated into the research and adoption lag (Hastings, 1981), or included in measuring the rate of adoption (Bezar, 1993). The impact of research depreciation is unlikely to be as large as some of the other factors due to the discounted nature of the returns; by the time research depreciation is likely to occur, the returns will be comparatively smaller than in the earlier years.

# COVER COMB TECHNOLOGY

## Description of the Cover Comb

The initial cover comb was made by Sunbeam Corporation Ltd and distributed by Agrisales Ltd. The Heiniger high country comb, which came onto the New Zealand market in 1994, and the Chinese John Hand comb which has recently (1995) come onto the market, are also cover combs. The different brands of cover comb are also referred to generically as winter combs (Kidd, R., 1997, personal communication). The cover comb has nine teeth (compared to the 12 or 13 teeth on a conventional comb), with skids on every second tooth. Fewer teeth enable it to be pushed through the fleece with more flattening of the fibres than a conventional comb. The skids on the teeth also lift the comb a few millimetres further from the skin than a conventional comb (Kidd, R., 1996, personal communication). As a result cover combs leave about 5 to 7 millimetres of stubble on the sheep, compared to the 2 to 4 millimetres left by a conventional comb. This increases the sheep's insulation against cold wet weather (Dabiri, 1994). Parker *et al.* (1989) reported that the residual wool was 3 to 4 times greater in cover comb-shorn sheep than conventional comb-shorn sheep. A later trial measured residual fleece on cover comb shorn sheep at 8.75 $mg/mm^2$ compared to 4.24, 3.06, 3.75 and 2.88 $mg/mm^2$ on sheep shorn with a Super 9 comb, a Big 10 comb and two types of conventional combs, respectively (Burnham, D., 1996, personal communication).

## Advantages of Cover Comb Use

The extra depth of stubble left on the sheep after shearing with a cover comb compared to shearing with a conventional comb increases the sheep's insulation leading to greater cold resistance (Holmes *et al.*, 1992). This increased cold resistance can reduce feed intake or live weight loss, and lead to fewer losses, in sheep shorn in adverse conditions such as those that occur in winter and early spring. The thermoregulatory advantages afforded by the cover comb are greatest in the first two weeks post-shearing, and especially in the first three days after shearing (Holmes *et al.*, 1992). Beyond this time, wool regrowth has been sufficient to counter the effects of bad weather.

*Reduced Cold Stress*

Recent trials have shown reduced post-shearing cold stress in sheep shorn post-shearing with a cover comb compared to those shorn with a conventional comb (Parker *et al.*, 1989; Holmes *et al.*, 1992; Dabiri *et al.*, 1995b). Differences in rectal temperatures and metabolic activity were used as measures of cold stress.

Oxygen consumption is directly proportional to rates of heat production and therefore heat loss. Holmes *et al.* (1992) found oxygen consumption increased by 47% and 25% post-shearing for conventional and cover comb-shorn hoggets, respectively, exposed to 10°C temperatures. Differences between the two groups remained significant until 22 days post-shearing. A later trial which exposed non-pregnant, non-lactating ewes to cold, wet and windy conditions showed heat production to be 22% to 38% greater in conventional comb-shorn ewes than in cover comb-shorn ewes (Dabiri *et al.*, 1995b).

Changes in plasma metabolite concentrations are used as an indicator of nutritional stress. Where body energy reserves are being to mobilised to increase heat production to maintain deep body temperature, levels of non-esterified fatty acids and 3-hydroxybutyrate rise (Parker *et al.*, 1989; Dabiri *et al.*, 1995b). Levels of plasma metabolites between the cover comb- and conventional comb-shorn sheep were significantly different in the first three days after shearing, indicating the higher mobilisation of body reserves for heat production by conventional comb-shorn sheep (Holmes *et al.*, 1992; Dabiri *et al.*, 1995b.)

Hutchinson *et al.* (1960) found ewes shorn with a snow comb (stubble depth 12 mm) had higher skin and rectal temperatures and a lower heart rate than conventional comb-shorn ewes (stubble depth 5 mm) exposed to cold, windy conditions. Where sheep were exposed to these conditions for 18 to 20 hours, 7 of the 8 conventional comb-shorn sheep but only 1 of the 8 snow comb-shorn sheep had to be removed due to weakness and hypothermia. Husain (1996) and Dabiri *et al.* (1995a) also found that rectal temperatures were significantly lower in pre-lamb shorn sheep compared with unshorn sheep on some days post-shearing, with no significant difference between those shorn with a cover comb and those shorn with a conventional comb. However, five days after shearing only the conventional comb-shorn sheep were significantly lower, indicating the ability of cover comb-shorn sheep to more quickly recover from shearing (Dabiri *et al.,* 1995a).

*Reduced Losses*

Ewe deaths following pre-lamb shearing are primarily caused by hypothermia. The lower heat production by cover comb shorn ewes implies that their heat loss under extreme conditions is less, and therefore they are less likely to die from hypothermia (Dabiri *et al.*, 1995b). Some past research results have shown ewe losses to be greater in conventional comb-shorn sheep post-shearing, than in either cover comb-shorn or unshorn sheep in cold, wet and windy conditions (Hutchinson, 1968; Dabiri *et al.*, 1995a).

Dabiri *et al.* (1995a) found ewe losses of 3, 14 and 3% for ewes pre-lamb shorn with a cover comb, standard comb and unshorn till post-weaning, respectively. In this trial several days of adverse weather conditions occurred from the fourth day post-shearing. Most sheep losses occur in the two weeks post-shearing (Dabiri, 1994). Losses may have been higher had the shorn ewes not been housed during one particularly bad storm (Parker *et al.*, 1995). These results demonstrate that under severe weather conditions the extra wool left on cover comb-shorn ewes increases their insulation and reduces deaths.

To identify the reduction in losses due to shearing with a cover comb rather than a conventional comb, the likely level of losses post shearing with a conventional comb needs to be known. Post-shearing losses can be variable between years, regions and farms.

Studies on post-shearing mortality were conducted in Australia in the 1960s. Hutchinson (1968) surveyed post-shearing mortality over three years. Losses recorded were 0.68% of sheep shorn and of these 0.5% occurred in the first two weeks of shearing. Geytenbeek (1962) found post-shearing losses to be 8.3% following heavy storms, with mortality being 12.2% for those shorn for five days or less, and 0.7% for those shorn between 8 to 12 days. A trial conducted by Hutchinson and McRae (1969) measured losses averaging 21% and 24% for two flocks, with a range of 0 to 75% losses within groups. In a further study, 27% of the ewes died in the shorn group post-shearing while only one ewe in the unshorn group died. The majority of these sheep died in the first few days. A relationship was found between the plane of nutrition pre-shearing and mortality: sheep which were losing weight prior to shearing were more likely to die. There appeared to be little relationship between actual body weight and mortality. In contrast, some New Zealand trials have shown no significant difference in losses between pre-lamb shorn ewes and unshorn ewes (Everitt, 1961; Sumner and Scott, 1990; Dabiri *et al.*, 1994). Differences in climatic conditions post-shearing probably explain the variation in losses between the studies. The greatest mortalities in these studies consistently occurred in the first few days post-shearing, which is when the cover comb has its greatest effect. These results suggest that where there is a risk of inclement weather post-shearing, such as in winter or early spring, the use of a cover comb could be effective in reducing sheep losses to those of unshorn sheep.

*Reduced Feed Intake*

In order to identify the effect of cover comb, rather than conventional comb shearing, on feed intakes post-shearing it is first necessary to identify the likely increases in feed intake post-shearing with a conventional comb. A number of studies have been reported on the effect of shearing on feed intake. Several of these show shearing was associated with increased feed intake, although the changes in intake following shearing were variable. In summarising these trials, Dabiri (1994) suggested these differences were due to climatic effects post-shearing, availability of feed, type of diet, adaptation to cold, class of stock, whether ewes were pregnant or non-pregnant, and whether the trial was indoors or outdoors.

The results of recent trials comparing intakes in pre-lamb shorn ewes and unshorn ewes under New Zealand grazing conditions have been consistent with those of some past trials. Dabiri *et al.* (1996) found increases in organic matter intake were delayed in pre-lamb shorn ewes compared to unshorn ewes: there were no significant differences in intake in the 11 days after shearing, however 23 days after shearing shorn ewes had an intake significantly greater than that of unshorn ewes (12% difference). There was no difference in intake during lactation. In a later trial (Dabiri *et al.*, 1995a) comparing ewes pre-lamb shorn with conventional and cover combs with unshorn ewes, the intake of conventional comb-shorn ewes was 16% greater than that of unshorn ewes 9 to 12 days after shearing, with no significant difference between the cover comb-shorn and unshorn ewes. Parker *et al.* (1991) measured a 17% increase in the post-shearing intake of shorn ewes. Husain (1996) recorded no significant differences in organic matter intake between ewes shorn with a conventional comb, a cover comb and unshorn in the 12 days post-shearing. In the same trial no significant difference was recorded in organic matter intake between ewes set-stocked on pasture with sward surface heights of 3, 5 and 7 centimetres, except on the second day following shearing. These results suggest hypothermia induced by pre-lamb shearing cannot be avoided by pasture management, provided surface sward exceeds 3 centimetres (Husain, 1996).

Past trials have found post-shearing intake increased from 5% to 78% (Wheeler *et al.*, 1963; Wodzicka-Tomaszewska, 1964; Hutchinson and McRae, 1969; Elvidge and Coop, 1974; Vipond *et al.*, 1987). Most of these trials have been with non-pregnant sheep, housed pregnant ewes or penned sheep and feed intake responses to shearing will not necessarily be the same as those of sheep at grazing.

Vipond *et al.* (1987) ran a series of three trials using housed pregnant ewes to compare shearing, breed and diet interactions. The increases in intake due to shearing for the three experiments ranged from 5% to 43%. It is interesting to note that in experiment one, ewes were shorn with a number 3 comb (6.25 mm thick) whereas in the other two trials they were shorn with a standard comb (3.125 mm thick). Diets were similar for experiments one and two (barley and silage). The sheep in trial one were in the 16th week of gestation compared to the 12th week for those in the other trials. Sheep breeds also differed for the trials. The increase in feed intake in trial one was 16%, and in trial two 43%. In trial two the intake increase for the larger Greyface sheep, which would be similar in size to those in trial one, was 30%. Although conclusions are unable to be drawn due to differences in stage of gestation and breed, it is possible that differences in shearing comb used also contributed to the lower increase in intake in trial one.

Dabiri (1994) suggested that the greater feed intake and resting heat production of pregnant and lactating animals may reduce the effect of shearing on feed intake in these ewes compared to that in non-pregnant sheep. He supports this argument by citing the results of a grazing trial by Hudson and Bottomley (1978) in which the effect of shearing on feed requirements of dry and pregnant (13-20 weeks) ewes were compared. In the eight weeks after shearing maintenance requirements increased 47% for dry ewes, but only 15% for pregnant ewes. The 15% increase in intake is similar to that reported for New Zealand grazing trials (Parker *et al.*, 1991; Dabiri, 1994; Dabiri *et al.*, 1995a). Feed intake in late pregnancy may be restricted, and fail to meet the increasing demands of pregnancy, due to metabolic changes and changes in rumen volume. Feed responses of ewes shorn in late pregnancy may also be limited for these reasons (Dabiri, 1994).

Increases in feed intake after shearing can be delayed, reaching a peak after 3 to 4 weeks then declining, as measured by Wodzicka-Tomaszewska (1964) in non-pregnant ewes. Parker *et al.* (1991) recorded only small and non-significant increases in intake in pre-lamb shorn ewes during pregnancy, but these increased and were significant during lactation. In contrast, two recent trials recorded significant differences 1 to 3 weeks after shearing, but these differences only persisted for a short time i.e. 10 to 20 days after shearing, during pregnancy (Dabiri, 1994).

In summary, the results of research on the effects of shearing on feed intake have been varied. Under grazing conditions in New Zealand, pre-lamb shearing of ewes has been shown to increase feed intakes from 0 to 17%. In one trial, feed intake of ewes pre-lamb shorn using a cover comb was not significantly greater than that of unshorn ewes, compared to a 16% increase in ewes shorn with a conventional comb (Dabiri *et al.*, 1995a). Factors most likely to affect feed intake responses to shearing under New Zealand grazing conditions are climatic conditions, feed quality and availability, and condition of stock. Feed savings from using a cover comb rather than a conventional comb at shearing may be greater for non-pregnant stock such as hoggets, lambs or ewes at other times of the year, where feed intake post-shearing may increase to a greater extent and last longer, than in pre-lamb shorn ewes. Several trials, mainly with dry sheep, have shown that cold stress reduces the ability of animals to digest their feed, and this is likely to place shorn animals under additional nutritional stress (Dabiri, 1994). The use of a cover comb for shearing will reduce cold stress, which in turn may increase the amount of feed digested, so increasing production.

*Reduction in Live Weight Loss*

The greater insulation provided by the greater depth of stubble left on the sheep after shearing with a cover comb compared to a conventional comb, lowers heat production (Holmes *et al.*, 1992; Dabiri *et al.*, 1995b), enabling either a greater portion of absorbed nutrients to be partitioned towards increasing production or a reduction in mobilisation of body reserves, so reducing live weight loss.

Both reduced live weight gain and increased live weight loss have been reported in shorn sheep compared to unshorn sheep (Elvidge and Coop, 1974; Dabiri *et al.*, 1995a; Husain, 1996). In other trials no significant differences have been found (Wodzicka-Tomaszewska, 1964; Parker *et al.*, 1991). Dabiri *et al.* (1995a) found unshorn ewes were significantly heavier than ewes shorn with a cover comb, which were in turn significantly heavier than ewes shorn with a conventional comb, twenty days after shearing. At weaning there was no significant difference between groups of ewes. The shorn ewes would have either had to increase intakes or partitioned a greater proportion of nutrients towards regaining this live weight rather than production, to attain similar live weights to unshorn ewes at weaning. The use of a cover comb has an advantage over a conventional comb for shearing in reducing this energy loss.

*Animal Welfare and Peace of Mind*

There are also non-measurable benefits of using a cover comb rather than a conventional comb for shearing in winter and early spring, when adverse climatic conditions can occur. In recent years animal welfare issues have become very important, from both an international and a New Zealand perspective. These can have economic implications as animal rights or animal welfare issues are being used, both positively and negatively, as a marketing ploy. The discomfort incurred by sheep shorn in adverse climatic conditions and the greater risk of losses associated with this cold stress has not become a major "issue" to date, however New Zealand farming practices are now more closely monitored than in the past. The development and uptake of cover comb technology to reduce the risk of death and discomfort in sheep post-shearing is likely to be regarded favourably by animal welfare lobbyists.

Animal welfare issues are also important to most farmers. The use of a cover comb for shearing in winter or early spring is likely to afford the farmer greater "peace of mind", knowing his/her sheep are more comfortable and better able to withstand bad weather. The reduced risk of sheep losses also has economic implications. There are also likely to be labour-saving aspects because of a reduced need to shed sheep or shift them to more sheltered areas when the weather is inclement. Shearers using a cover comb to shear in winter and early spring may also have greater "peace of mind" and job satisfaction, knowing sheep they have shorn are more comfortable (Kidd, R., 1996, personal communication).

**Applications for Cover Comb Use**

*Pre-lamb Shearing*

There are management and financial advantages to pre-lamb (full wool) and eight monthly ewe shearing policies (Parker and Gray, 1989). These policies require sheep to be shorn in winter or early spring (every third shearing, for eight month shearing policies), with the associated disadvantages of increased risk of losses and possibly greater feed intake. These disadvantages can be partly offset by the use of the cover comb for winter shearing. Farmers unwilling to take the risk, may now consider these shearing policies, and use the cover comb to offset the disadvantages. These disadvantages can also apply to second shear policies, shearing post-tupping (Livingston and Parker, 1984), and the use of a cover comb at shearing is likely to be beneficial in this respect.

The advantages of a pre-lamb shearing policy over a conventional full wool policy include improved cashflow and reduced overdraft charges, lower shearing costs due to the elimination of pre-lamb crutching, less wool lost from ewes that die over lambing, reduced casting of ewes, better labour distribution over spring and summer, greater flexibility with weaning and sales of dry ewes, greater availability of shearers, and better wool quality which, with the possibility of out-of-season premiums, may increase wool income (Livingston and Parker, 1984; Parker and Gray, 1989; Dabiri *et al.*, 1994; Parker *et al.*, 1995). A premium for the wool of pre-lamb shorn ewes may be earned because the wool has better colour, yield and fibre strength compared to the wool of summer-shorn full wool ewes (Story, 1955; Story and Ross, 1959; Story and Ross, 1960; Geenty, 1992). Pre-lamb and eight month shearing policies reduce shearing costs, improve wool length and decrease labour requirements relative to a second shearing policy. Farm trials indicate the advantages of eight month shearing policies are intermediate between those of second shear and full wool policies (Geenty, 1992 ; Sumner *et al.*, 1992). Sumner and Scott (1990) found net wool returns from ewes shorn once yearly in July exceeded those of ewes shorn twice yearly, which in turn exceeded those of ewes shorn once yearly in January. This concurs with the finding of Parker *et al.* (1995) of $1.54 more per ewe on a pre-lamb shearing policy compared to a conventional full wool policy (adapted from Dabiri, 1994). As well as the advantages to the grower, pre-lamb and eight month shearing policies allow better continuity of work for shearers and wool handlers, a more continuous supply of wool for marketers and a greater variety of wool types for manufacturers (Geenty, 1992).

*Alternative to Blade Shearing*

Blade shearing is still used in some parts of the South Island to protect sheep from the cold after wool harvesting. Blade shearing is more expensive than handpiece shearing, and the availability of blade shearers can also be a problem. Cover comb shearing is a cheaper alternative to blade shearing, but provides greater protection compared to a conventional comb. While blade shearing still affords more protection to the sheep than cover comb shearing (Burnham *et al.,* 1995), the difference can be reduced by fitting a lifter (also called a riser) with a cover comb to further increase the amount of wool left on the sheep.

*Hogget and Lamb Shearing*

Hoggets are usually shorn in the months of August to October when adverse weather conditions for shearing are common. The use of a cover comb for hogget shearing would reduce the risk of hogget losses, and afford the farmer greater peace of mind. While farmers tend not to "own up," large numbers of hoggets have been lost in unexpected storms after spring shearing. The losses incurred are substantial and easily exceed the extra cost of cover comb shearing.

Lambs can also be vulnerable if cold, wet, windy weather occurs after shearing, even in December. The cover comb could be used for lamb shearing in some districts to reduce the risk of losses. While there is no trial work to substantiate feed saving advantages and possibly better feed utilisation with cover comb-shorn lambs (i.e. more energy being used for weight gain rather than keeping warm) compared to conventionally shorn lambs, the research reviewed earlier in this Chapter suggests that this is likely.

**Alternatives to Cover Comb Use**

The Gould lifter has recently been developed for use with a cover comb, and leaves more wool on the sheep than a cover comb only. This technology has been developed as an alternative to blade shearing. As this technology is used with a cover comb, rather than instead of a cover comb, it will not make cover comb technology redundant. However, the development of a technology that incorporates the features of a lifter and a cover comb could impact on the level of cover comb uptake.

Blade shearing is used in some parts of New Zealand, because of the greater protection from adverse climatic conditions afforded to the sheep after shearing, compared to mechanical shearing. The greater protection offered by cover combs compared to conventional combs (Holmes *et al*., 1992) may have resulted in an increase in sheep being cover comb shorn rather than blade shorn. Blades provide greater protection than a cover comb (Burnham *et al*., 1995), and it is possible, should there be dissatisfaction with cover comb shearing, a swing back to blades could result, in turn reducing cover comb technology uptake. This is likely have only a minimal effect due to the small number of sheep blade-shorn.

# MODELLING

## Definition of Modelling

A model is a representation of the real world, simplified for some purpose (Spedding, 1988). Only the key features of reality are represented, in order to make them easier to manipulate (Doyle, 1990). Models can be mental, stated (written or drawn), or more abstract and expressed in the form of equations i.e. mathematical, and can be applied to a system or a sub-system (Spedding, 1988). The advent of computers has enabled more complex interactions to be studied using mathematical models or simulation models (Doyle, 1990).

A model is used to assist in the understanding of a system, to determine gaps in existing knowledge, or to predict or monitor system performance (Spedding, 1988). Simulation models are used for decision support (Dent and Blackie, 1979). Models are useful where: it is impractical or impossible to study the real system; experimentation may not be feasible due to time and cost factors; and/or measurement may disturb the real system to the extent that observations relate to something artificial (Doyle, 1990). It is important to note that the usefulness and value of a model is only in relation to the purpose for which it was constructed (Spedding, 1988). This also applies to the system for which the model was designed.

## Model Development for Systems Simulation

There are a number of stages in the construction of the model . Figure 1.1, from Dent and Blackie (1979), shows the basic steps in the development of a simulation model to represent a system. The first step is to define the purpose of the model, in terms of the problem(s) the model will be used to solve and the degree of detail required; then to define the boundaries of the system the model applies to (Dent and Blackie, 1979). This includes deciding which variables to have in the model and which to leave out (Spedding, 1988).

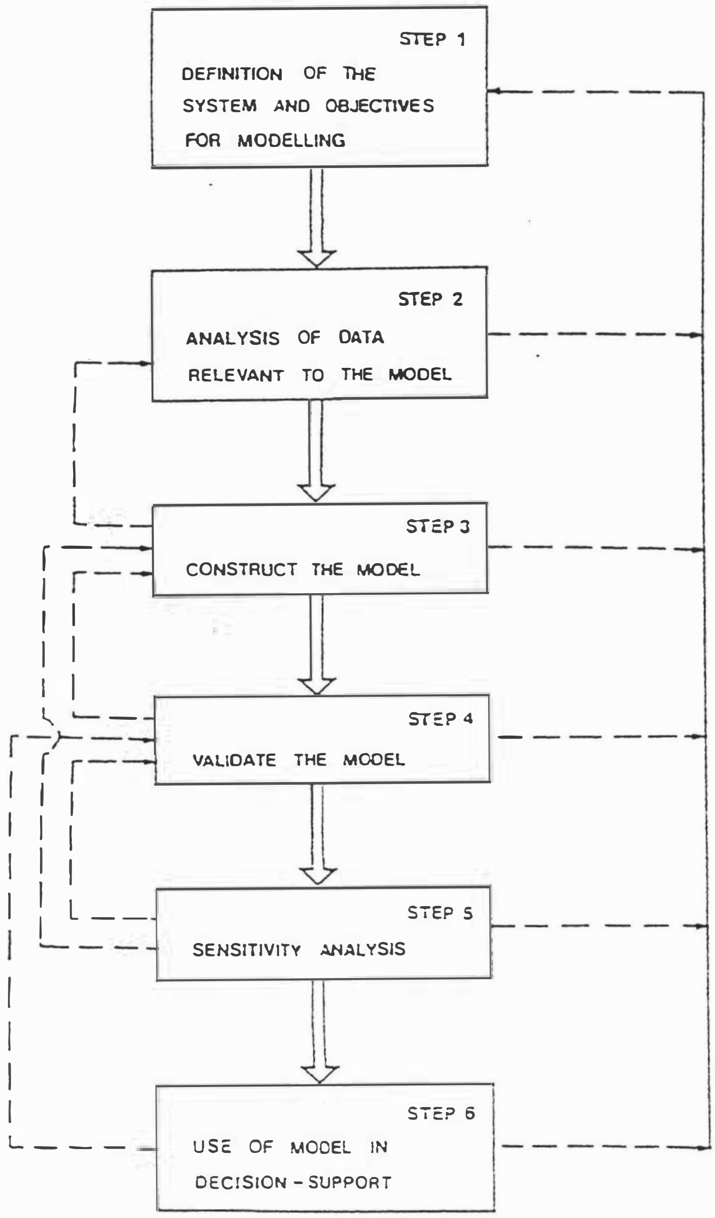


Figure 1.1 : Basic steps in development of a model for systems simulation (Dent and Blackie, 1979).

The next step is data analysis (Dent and Blackie, 1979). The basic framework of the model must be defined, and the design used is dependent on the data available or the feasibility of generating data.. A general diagram is drawn, outlining the components of the system to be modelled and the inter-relationships between these components. The dynamics of the system to be studied are then added to this diagram.

This is followed by a detailed data search (Dent and Blackie, 1979). Limitations at this stage may necessitate redesigning the model, further research to generate the required data or the adoption of alternative procedures to estimate the data. These limitations may arise because: alternative ways of representing system components may be more effective; data may be available, but in a format unsuitable for the model (which may be either rejected or modified); or data for specific relationships or rates of change are unavailable. Where values are estimated, it is important to check the sensitivity of the model to changes in these parameters once the model has been developed. The basic model structure and data requirement have now been defined. If required, time aspects are now included in the model definition and a diagram which is readily translated to a computer program is drawn. An appropriate computer language or software application in which to develop the model is then selected, and the model constructed.

The model is then verified and validated (Spedding, 1988). Verification checks the accuracy of the processes and interactions on which the model is based, represented by the equations in the model (Spedding, 1988). Validation establishes whether the model behaves in a fashion similar to the system being modelled, with sufficient precision and accuracy to meet the model's requirements. The model is tested using data other than that with which it was developed. This process is on-going over the model development, formal validation and application stages (Dent and Blackie, 1979). Assessment of the model *ex ante* can be difficult, and some form of subjective judgement may be required.

Sensitivity analysis is conducted on the completed, and at least partly validated, model and may continue on into model application (Dent and Blackie, 1979). The value of a single parameter is changed and the output analysed, to determine the model's sensitivity to that variable. Sensitivity analysis can be useful for: identifying variables likely to be sensitive in the real system, and therefore of interest in the management of the system; identifying sensitive variables that there may be concern about, possibly requiring model modification to reduce its sensitivity to these areas; and identifying sensitive variables for further investigation.

The final stage in the modelling process is application. Here the simulation model can be used to direct further systems analysis or to assist in management and development of the real system (Dent and Blackie, 1979).

# PURPOSE AND SCOPE OF THE STUDY

## Aims and Objectives

The objectives of this research were to quantify:

1. the costs of the research, development and extension of cover comb technology;
2. the financial benefits of cover comb technology, from both on-farm and industry perspectives; and
3. the return on investment in cover comb technology research, development and extension.

This information was then used to develop a model to assess costs and benefits of on-farm research opportunities using cover comb technology as an example.

The hypotheses are that:

1. the return on the investment made by Wools of New Zealand in research on cover comb technology is positive, and comparable to the return on other investment options;
2. a model for the *ex ante* economic analysis of on-farm research can be developed using an *ex post* economic analysis of cover comb shearing technology research.

## Thesis Outline

The first chapter of the thesis provided a context for the study from a review of the literature. The cost of the cover comb technology research, development and extension is quantified in Chapter Two. In Chapter three the findings are presented from surveys of shearing contractors, wool production officers and cover comb manufacturers, to determine the uptake of cover comb technology.

The development of a model for the *ex post* economic analysis (cost-benefit analysis) of cover comb technology research, development and extension is documented in Chapter Four. Benefits associated with cover comb technology are defined. The return to the investment in cover comb technology research, development and extension by Massey University and Wools of New Zealand is calculated. Sensitivity analyses are conducted to evaluate the impact of different benefits or uptakes on the return.

In the final chapter, a general discussion, summarising the overall results of this study in relation to its objectives is presented.

# CHAPTER TWO

# COVER COMB TECHNOLOGY : THE COST OF RESEARCH, DEVELOPMENT AND EXTENSION

## INTRODUCTION

The cover comb was developed from the snow comb by Sunbeam Corporation Ltd and Wools of New Zealand (WONZ) in the 1970's to imitate the effect of blade shearing. To evaluate the effectiveness of the new technology in terms of sheep protection from inclement weather post-shearing and efficiency of feed utilisation, six research trials, jointly funded by Massey University and WONZ, were conducted at Massey University between 1989 and 1995. These included both field and calorimetry trials as described in Appendix I. For the purposes of this research, the trials have been numbered from 1 to 6.

Field trials 1,3 and 6 were conducted in 1989, 1992 and 1994/95, respectively, and compared ewes shorn with a cover comb to those shorn with a conventional comb or left unshorn (Trials 3 and 6). Trials 2 and 4 were conducted indoors in a calorimeter in 1990 and 1992, and compared sheep shorn with a cover comb or a conventional comb. The 1995 calorimetry study (Trial 5) compared cover comb shearing with blade shearing. The three field trials measured the effects of pre-lamb shearing on feed intakes, cold stress, losses and lambing performance. The calorimetry trials measured the effect of shearing method on cold stress in sheep.

This chapter will identify the costs, and the timing of the costs, associated with the cover comb development, the six research trials and the related extension. The sources of information and assumptions made in calculating these costs will be described.

# METHODS

A cost-benefit analysis was used to calculate the return on investment in research on cover comb shearing technology. Historically, university research has been marginally costed and advantaged by the substitution of postgraduate training for labour costs and the use of educational facilities for commercial research. The research proposals were based on these marginal costs, which do not reflect actual costs. Thus all research and development expenditures were recosted on the basis of the Public Good Science Fund (PGSF) model which can be appropriately used to estimate the true return on investment in cover comb research. Costs and benefits are expressed in 1996 New Zealand dollars.

## Calculation of Research Trial Costs

The costs involved in the six research trials were determined from internal Massey University records and from the publications describing the six trials. The internal documentation consisted mainly of research proposals and associated correspondence. In some cases, minor changes or additions were made to the trial procedure or costings after the acceptance of the initial proposals, in order to optimise the research design relative to conditions and constraints at the time of the actual experiment. These were identified from the "Methods and Materials" sections of the publications and discussions with the researchers concerned, and costed accordingly.

## Full Costing of the Trials

Massey University cost recovery charges for 1996 were used to derive the analysis and data measurement costs, to represent their full cost to the University. Where full costs were known and differed from external costs, as in the case of research unit costs, actual costs were used. Staff salaries were based on the award effective from 1 January 1995. Labour and equipment provided free to the research was assigned an opportunity cost based on prevailing commercial rates. Overheads were assumed to be 100 percent of salary costs. A breakdown of the costs used in the analysis for each of the six trials can be found in Appendix II.

## Use of the PGSF Model for Costing the Trials

The PGSF model used by Massey University for research costs was adopted. A Microsoft Excel spreadsheet template which simulated the PGSF model was used to calculate the full research costs. The categories used, and assumptions made, in the PGSF model provided a standard method for costing the research, in a manner similar to that either currently used or likely to be used for future research proposals. The PGSF spreadsheet, which allows for trial expenditure to be allocated over three years, includes six cost categories: personnel, general operating, premises, equipment depreciation and rental, overheads and extraordinary expenses.

### *PGSF Personnel Costs*

The names of the staff included in the trials have not been used in the breakdown for confidentiality and privacy reasons; they are instead referred to as "Person A" to "Person H". The ACC levy is calculated at 1.71% of salaries paid. Superannuation costs are calculated at 4.5% of salaries paid. There is provision in the PGSF spreadsheet for new staff but this was not required for the trials analysed in this study.

### *PGSF General Operating Costs*

Operating costs could have been broken down into 15 different categories in the PGSF spreadsheet, but this was not necessary because most of the trial costs could accurately and more simply, be included under "Materials and Consumables". Some categories in the spreadsheet were assumed to be included in the overheads for the six research trials, for example, report preparation, library costs and telephone costs. Also some labour costs (casual labour, data collection and analysis, and shearing) were included under "General operating costs", because it was not possible to separate these from other operating costs. These labour costs also related to specific trial costs rather than to staff salaries as allowed for in the PGSF spreadsheet personnel costs.

*PGSF Premises Costs*

The PGSF premises costs for laboratory-intensive research are calculated as the proportion of time spent on laboratory-intensive research multiplied by 0.057 multiplied by total salaries. The 0.057 multiplier is based on the area of the premises multiplied by $180/m$^2$, the number of people working in the premises, and their salaries (Brown, D., 1997, personal communication). Field-work premises costs were allowed for in the past, but are no longer considered appropriate, although the spreadsheet template used still allows for these. The proportion of time involved in laboratory-intensive research was estimated, after discussions with researchers, to be half for the three field trials (trials 1, 3 and 6), one quarter for two of the calorimetry trials (trials 4 and 5) and zero for trial 2.

*PGSF Equipment Depreciation*

Depreciation of computers, computer-driven equipment and other equipment is allowed for in the PGSF breakdown, at rates of 0.33, 0.20 and 0.10 respectively, times the cost of the equipment and the fraction of time used. The PGSF guideline assumes computers are depreciated over three years. Computers were the only items depreciated for the six trials; other depreciation costs are incorporated into the overheads cost (see below). The cost of a computer was estimated at $2600. Further, it was assumed that each scientist had a computer available full time, and accordingly the scientist's time involved in the trial could be used to calculate depreciation. A postgraduate student was assumed to spend 10% of his/her time using Massey University computers for research, costed at the same rate as a personal computer for staff.

*PGSF Overheads*

The PGSF costing method adopts overheads at 100 percent of salary costs. This figure is commonly used by Massey University in its PGSF proposals. The overheads reflect the institutional costs of providing and maintaining facilities and support services.

*PGSF Extraordinary Costs*

Ten items are included under this category, but the only one used for this analysis was "Research unit costs". Casual assistance for extensive fieldwork would have been appropriate for some of the trials, but this was included under general operating costs as explained earlier. The trials were conducted at Massey University's Animal Physiology Unit (trials 2, 4 and 5), Sheep and Beef Cattle Research Unit (trials 1 and 3) and Ruminant Research Unit (trial 6). Research Unit costs were assessed at 1996 actual costs.

*Summary for the PGSF Objective*

Costs for each of the six categories in the PGSF budget (outlined above) were summed for each objective and GST was added at 12.5% to derive the total annual cost for the objective concerned.

**Other Assumptions Made in Calculating Research Trial Costs.**

A number of other assumptions were made in order to calculate the research trial costs. These are outlined below for the main items.

*Personnel Costs*

The need to protect privacy prevented the use of actual salaries, and thus the mid-point of the pay scale ranges for technicians (grade 7), senior lecturers, associate professors and professors was used for 1996 salaries (as at 1st January 1996). Assumptions made and salaries used to calculate personnel costs are summarised in Appendix II.

The opportunity cost of a postgraduate student's time was also derived. It was assumed that a masterate student spent half of his/her time on research and, of this time, half would be a learning experience and the balance would be doing the work of a technician. Therefore 25% of a masterate student's time and 50% of a PhD student's time, respectively, at the technician's salary level were used in the analysis.

*Shearing Costs*

Wools of New Zealand shearers shore the sheep for all six trials, either free of charge or at a low cost. The opportunity cost of labour for shearing was calculated at $1.60/sheep for all trials. However, because shearing only a few sheep at a time is uneconomic from a commercial point of view, an opportunity cost for the Wools of New Zealand shearer's time in travelling and expenses was included in the shearing costs for trials 1, 2, 4, 5 and 6. This increased shearing costs by an extra $58 per trial (or up to $6.42 per sheep) (Appendix II).

*Data Collection and Analysis Costs*

Analysis and data collection costs were assessed at the University's 1996 external costs rate. The main analysis items for this study were: faecal chromium analysis at $22.05 per sample; digestibility analysis at $22.30 per sample; non-esterified fatty acid analysis at $3.92 per sample and glucose analysis at $2.93 per sample. The wool analysis costs varied between trials; these were based on a cost per sample in trials 1 and 3, cost per hour in trial 5, and a total cost in trial 6. Data collection charges were based on number of samples collected per hour and either an hourly rate and the number of samples collected per hour or a cost per sample (Appendix II).

*Casual Labour Costs*

In the original proposals labour for the trials was costed at either $11.50 or $12.00 per hour, except for the first trial where casual wages were budgeted at $9.00 per hour. Labour costs for trial 1 were adjusted to $11.50 per hour to represent 1996 charges, and the other trials were left as originally budgeted, as both $11.50 and $12.00 per hour were within the 1996 pay range for casual labour (Appendix II).

*Chromium Capsule Costs*

Chromium capsules were used in the trials to measure feed intake. These were entered at their 1996 purchase cost of $12.00 each.

*Feed Costs*

Lucerne hay for the calorimetry trials was costed at the 1996 price of $1.25 per kilogram.

## Development Costs

The development costs for the cover comb were based on information provided by Agrisales NZ Ltd, distributor of the Sunbeam cover comb. Information on the development costs, the timing of these costs and a brief description of these activities was provided. These costs were in Australian dollars. The exchange rate in the year the costs were incurred, and the consumer price index, were used to convert the costs to 1996 New Zealand dollars. The exchange rate and consumer price weighted index values were those prevailing at the start of January in the year the costs were incurred (Appendix III).

## Extension Costs

Wools of New Zealand costs associated with extension activities for the cover comb between 1991 and 1996 were calculated based on time spent by the Wool Production Officers in cover comb technology-related extension activities and the cost to Wools of NZ of employing an extension officer (average salary and overhead costs). Massey University extension costs were assumed to be included in the research costs in terms of staff professional time and overheads.

*Wools of New Zealand Extension Costs*

A questionnaire was sent to the Wool Production Officers in July 1996, requesting data on their cover comb extension activities and the adoption of cover comb technology in their regions (Appendix V and Chapter 3). Questions one to six were used to define extension activities and obtain the data required to calculate cover comb extension activity costs. This could be provided two ways: either as an estimate of their hours involved in cover comb extension activities and other costs associated with cover comb technology extension, or as an estimate of the proportion of their time spent on cover comb activities. "Hours spent per annum on cover comb extension activities" was provided by, or calculated for, the Wool Production Officers based on information provided. Hours per annum spent on cover comb activities and the cost of employing a Wool Production Officer was used to calculate the "total cover comb extension activities" cost. The cost to Wools of New Zealand of employing a Wool Production Officer was assumed to be $50/hour, based on a 1996 total cost (salary plus overheads) to Wools of New Zealand of employing a Wool Production Officer at $100,000 per annum (Geenty, K., 1996, personal communication), and a working year of 2000 hours/annum. Final costings from the analysis of cover comb extension activities were confirmed with Wools of New Zealand staff.

# RESULTS

## Research Costs

The combined marginal cost of the six trials, based on the original proposal costings, came to $113,013, exclusive of GST (Table 2.1). The proposal costs are nominal costs (taken directly from the proposals), but due to the low inflation over recent years (Statistics NZ, 1995) these costs would be similar in 1996 terms. Massey University paid all the scientists' salary costs. Operating costs and technicians salaries were paid by Wools of New Zealand, Massey University and the Vernon Willey Trust, and overheads and extraordinary costs (research unit costs) were paid for by Massey University and Wools of New Zealand. Personnel costs accounted for 48.2% of total costs, operating costs 25.3%, overheads 21.8% and extraordinary costs 4.7%.

**Table 2.1 : Summary of cover comb research costs ($) for the six trials conducted at Massey University, based on original proposal costs (GST exclusive).**

| Cost | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Total |
|---|---|---|---|---|---|---|---|
| **Year** | **1989** | **1990** | **1992** | **1992** | **1995** | **1994/95** | |
| **Costs** | | | | | | | |
| **Personnel** | 2724 | 10000 | 7969 | 7014 | 7466 | 19300 | 54473 |
| **Operating** | 399 | 980 | 4278 | 3780 | 1383 | 17810 | 28630 |
| **Overheads** | 463 | 4500 | 4090 | 3507 | 2425 | 9650 | 24635 |
| **Extraordinary** | 150 | 0 | 2700 | 285 | 140 | 2000 | 5275 |
| **Contributor[1]** | | | | | | | |
| **Massey** | 3000 | 7800 | 10689 | 6761 | 4825 | 28950 | 62025 |
| **WONZ** | 736 | 7680 | 6126 | 7825 | 6589 | 19810 | 48766 |
| **VWT** | 0 | 0 | 2222 | 0 | 0 | 0 | 2222 |
| **TOTAL** | 3736 | 15480 | 19037 | 14586 | 11414 | 48760 | 113013 |

[1]WONZ = Wools of New Zealand, VWT = Vernon Willey Trust

The actual costs associated with the trials, based on the PGSF spreadsheets, both including and excluding the opportunity cost of postgraduate student input, are summarised in Table 2.2. The PGSF templates for each of these six trials are in Appendix IV.

**Table 2.2 : Summary of cover comb research costs for the six trials conducted at Massey University, both fully costed and excluding postgraduate (PG) costs (NZ$ 1996, GST exclusive).**

| Cost | Trial 1 | Trial 2 | Trial 3 | Trial 4 | Trial 5 | Trial 6 | Total |
|---|---|---|---|---|---|---|---|
| **Year** | **1989** | **1990** | **1992** | **1992** | **1995** | **1994/95** | |
| **Personnel** | 8991 | 17708 | 22771 | 16356 | 8604 | 40202 | 114632 |
| **Operating** | 9940 | 1962 | 8607 | 9613 | 3641 | 26896 | 60659 |
| **Premises** | 241 | 0 | 611 | 219 | 115 | 1078 | 2264 |
| **Depreciation** | 112 | 292 | 172 | 112 | 120 | 498 | 1306 |
| **Overheads** | 8465 | 16672 | 21440 | 15400 | 8101 | 37852 | 107930 |
| **Extraordinary** | 374 | 3250 | 6765 | 2850 | 1400 | 2700 | 17339 |
| **TOTAL** | | | | | | | |
| **Fully Costed** | 28122 | 39883 | 60366 | 44550 | 21982 | 109228 | 304131 |
| **Excluding PG** | 14228 | 26177 | 32663 | 17036 | 21982 | 81275 | 193361 |

Most costs related to the provision of human resources. The full cost of the trials exclusive of GST came to $304,131. Of this 37.7% ($114,632) was for personnel costs (scientists, technicians and postgraduate students), 36.7% ($111,500) related to the provision of facilities and equipment for employees i.e. overheads, depreciation and cost of premises, and 25.6% ($77,998) was for costs directly associated with the trials (operating and extraordinary costs). Extraordinary costs, in this case, were for the use of research units. The postgraduate-related costs came to $110,770, or 36.4% of the full cost of the trial.

The original proposal costs equated to 37.2% of the full costs. The proportion of proposed costs to full costs for each category came to 47.5%, 47.2%, 22.8% and 30.4%, for personnel costs, operating costs, overheads and extraordinary costs, respectively. The research proposals made no explicit allowance for depreciation or premises costs, although some or all of these may have been included in the "overheads" category. These costs are relatively small in comparison to the other cost categories and would not significantly alter the estimate of total trial costs.

The breakdown of research costs by year, required for the cost-benefit analysis model, is summarised in Table 2.3.

**Table 2.3 : Summary of annual timing of research costs for the six cover comb trials (NZ$ 1996, GST exclusive).**

| Year | 1989 | 1990 | 1992 | 1994 | 1995 |
|---|---|---|---|---|---|
| **Cost** | 28122 | 39883 | 104916 | 54614 | 76596 |

**Development Costs**

Cover comb technology was first suggested by Ian Rutherford twenty-five to thirty years ago. The design phase, factory and field trials, conducted in New Zealand in the early 1970s over two years, are estimated to have come to approximately A$35,000 (Locke, R., 1996, personal communication). For this study, these development costs are assumed to have been incurred in 1972 and 1973 at A$17,500 per year. Adjusted to 1996 New Zealand values, these costs are equivalent to NZ$152,711 and NZ$155,175, for 1972 and 1973, respectively.

Recent increase in demand for cover combs has led to a need for further investment in technology for their manufacture. This new technology was utilised in 1994, and came onstream in 1995/96. For this study costs were assumed to occur in 1995. These costs were estimated to be A$200,000 (Locke, R., 1996, personal communication), or $248,715 in 1996 New Zealand dollars .

**Extension Costs**

The amount of time spent by the eight Wools of New Zealand Wool Production Officers on cover comb technology varied considerably between officers, ranging from minimal to 100 hours/annum. A total of 200 hours/annum at a cost of $10,000/annum for the years 1991 to 1996 was assumed. The activities included in this estimate were cover comb technology research and the initial cover comb extension activities following the publication of the research results. All extension costs are in 1996 dollars.

**Total Costs**

The total cost of the development, research and extension of cover comb technology (excluding GST) comes to $920,732 in 1996 New Zealand dollars.

## DISCUSSION

**Research Costs**

There was some difficulty in identifying the actual costs incurred in the trials from the research proposals, associated correspondence and trial methodology, as this was not the original purpose of these documents. There will thus be some discrepancies between the estimated and actual costs incurred, due to the assumptions made, estimations used in costing trial procedures (based on the proposals and methods) and rounding errors. These differences are not expected to be great. A system to record actual research trial costs could be of use to the University for future evaluation of research.

The results indicate that past research proposals have greatly underestimated real trial costs. Research proposals ignore postgraduate-related costs, as these are not a cash cost to the University. Most direct personnel costs (excluding postgraduates) were accounted for in the original proposals (93.1%). This reduced to 47.5% when the postgraduate opportunity costs were included. Proposal operating costs were 47.2% of total operating costs, reflecting the degree to which these items were marginally costed for researchers within the University. The same applied to research unit costs; only 30.4% of these costs were allowed for in the proposals. Overheads have been underestimated in past research proposals; in this study proposal costs accounted for only 22.8% of full costs or 44.7%, excluding postgraduate costs. Depreciation and premises costs represent only a small proportion of total costs, and were not explicit in the proposals.

The marginal costing reflects the funding Universities receive for research through the education vote (variously estimated to be between 5% and 30% of the EFTS value). Thus, where postgraduate training is involved, it may not be appropriate to fully charge the research client and to also receive a proportion of education funding for the same purpose. Nevertheless, this analysis reflects the situation where the work would otherwise have been done by a technician. The opportunity cost is borne by both the student and /or scholarship provider for the time they devote to the project, and by the University or the Government through effective full-time student funding for the provision of facilities. It is therefore appropriate to fully cost the inputs of postgraduate students when estimating the benefits and costs of research.

The contribution made by Wools of NZ was 43.2% of the proposal costs, excluding most shearing costs. The latter increased their contribution by $788 to $49,554. The total Wools of New Zealand contribution represented only 16.3% of the full cost of the trials, or 25.6% of the full cost excluding the postgraduate student contribution. Therefore, most of the trial costs were borne by the University, through the education vote. Future research proposals are likely to be more explicitly costed, and the contribution towards research by outside organisations will therefore be expected to be somewhat higher, to reflect the true cost of research and the sector which ultimately benefits, as well as the appropriate amount of funding from student fees and the Government.

**Extension Activities**

Most extension activities relating to the cover comb in the last five years have been conducted by the Wools of New Zealand Production Officers and Massey University staff. Cover comb extension by Wools of New Zealand Production Officers is estimated at $10,000/annum initially, from 1991 to 1996. Massey University costs were assumed to be included in overhead and personnel costs.

Wools of New Zealand shearing instructors include cover combs in their winter shearing courses, and mention them in all other shearing courses (Kidd, R., 1996, personal communication). This is a valuable and effective means of extending cover comb technology as the use of cover combs is explained and demonstrated to those directly involved in the industry. However no cost is involved, as the objective of these courses is to provide shearing instruction which is paid for by the participants.

Wool Production Officers' extension activities included mention of cover combs at field days and discussion groups, and writing articles for publications and newspapers. Cover combs were often mentioned in discussions with clients or contractors in relation to other topics such as pre-lamb shearing, rather than being the primary purpose of the visit or discussion. This complicated the estimation of the time spent in cover comb-related extension activities. Massey University extension activities included the discussion of cover combs at field days, the inclusion of cover comb shearing in papers presented at the Central Districts Sheep and Beef Cattle Farmers' Conference and in scientific publications, liaison with Wools of New Zealand staff, and the printing of an extension booklet on cover comb shearing.

# SUMMARY

All costs, except proposed costs, were expressed in 1996 New Zealand dollars. Proposal costs were for the years in which they were incurred, but were not expected to differ greatly from their 1996 values, due to the low rates of inflation since 1991. The full cost of the research and extension activities came to $364,131 1996 New Zealand dollars, exclusive of GST. This cost was incurred between 1989 and 1996. Wools of New Zealand's contribution was $109,554; this included extension ($60,000), shearing ($1250) and other research costs ($48,304). The Vernon Willey Trust contributed $2222; the remainder of the cost was borne by Massey University and postgraduate students through labour. Full costs excluding the postgraduate contribution came to $253,361. Massey University's contribution was therefore $141,585. Postgraduate-related costs came to $110,770.

The results showed that the cost of University-based research has been underestimated in the past, even allowing for funding from sources other than the research client. Proposed trial costs came to $113,013; in comparison the full derived cost of the research came to $304,131.

The development costs were incurred entirely by the Sunbeam Corporation Ltd. These were NZ$307,886 for the design phase in the early 1970s, and NZ$248,715 for the utilisation of new technology to improve on the quality in the manufacture of cover combs in 1994/95.

In summary, the total cost of development, research and extension came to $920,732 in 1996 New Zealand dollars. Research and extension costs were incurred between 1989 and 1996, and development costs in 1972, 1973 and 1995.

# CHAPTER THREE

# ASSESSING COVER COMB[1] ADOPTION : FINDINGS FROM SURVEYS OF COVER COMB MANUFACTURERS, SHEARING CONTRACTORS AND WOOL PRODUCTION OFFICERS

## INTRODUCTION

To develop a cost-benefit analysis model of the returns on investment in a new technology, such as the cover comb, it is necessary, as one part of the analysis, to predict the technology uptake by end-users over time. Factors other than research and associated extension affect technology uptake (Rogers, 1983). Therefore, in assessing returns from research, the technology uptake both with and without the research needs to be estimated; the difference can be attributed to the research and associated extension programmes (Marsden *et al.*, 1980). Extension costs are included with the research costs, because without extension the uptake of technology is likely to be less rapid or not as great (Rogers, 1983). It is axiomatic that the shorter the lag phase (the time period between the research and the technology uptake) and the higher the adoption rate of the technology, the greater the benefits from the research. The level and rate of technology uptake before and after applied research can be used to disaggregate the proportion of uptake associated with the research, and to predict the uptake that may have occurred without the research.

An understanding of the reasons why the technology is being used, and by who, is useful for predicting the potential for further technology uptake and the likely ceiling level for the technology. Future technological developments likely to supersede the

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[1] The term "cover comb" is a brand name for the Sunbeam cover comb. The Heiniger high country comb and the Chinese John Hand comb have more recently come onto the market. The generic term winter comb refers to the Sunbeam, Heiniger and John Hand combs which leave additional wool on the sheep and are similar to the Sunbeam cover comb in terms of design. At the time of the trials reported in this thesis the Sunbeam cover comb was the only "winter" comb available, and therefore the trials were conducted using this cover comb. For the purposes of this study the term "cover comb" includes all three comb types unless specifically referred to as the Sunbeam cover comb.

technology in question also need to be considered, as these innovations have the potential to cause a decline in the future use of the technology.

Johnston *et al.* (1992) concluded that "the largest economic benefits are frequently associated with research that yields simple technologies that are quickly adopted and widely applicable, and lead to significant cost reductions in the industry. A low and slow adoption rate can greatly reduce economic benefits" cited by Bezar (1993). Marsden *et al.* (1980) concluded that the magnitude of the benefits of research are dependent on the likelihood of developing a cost-reducing technology, the magnitude of cost reductions, the extent and rate of adoption, and the size of the industry to which the adoption is applicable. In a similar view Reid *et al.* (1996), in developing a framework for understanding the adoption and use of technologies by dairy farmers, found technologies were more likely to be adopted if they were not overly complex, were compatible with experience and existing circumstances, had advantages over the current system, were easily able to be implemented or rejected as circumstances required, and reduced risk (allowing greater peace of mind).

Against this background, the adoption of cover comb technology could be expected to be rapid with high returns because it is a simple, risk-reducing, easily adopted technology that is applicable to a large agricultural industry. It generates financial advantages to end-users by reducing sheep losses and possibly conserving pasture when feed reserves are low (Parker *et al.*, 1995). It can increase the efficiency of labour by allowing a major farm operation, ewe shearing, to be completed during the usually "quiet" winter months. Once sheep are shorn with a cover comb the likelihood of having to shift them to shelter if inclement weather strikes is less than if standard shearing combs are used (Dabiri, 1994). The risks associated with pre-lamb or eight-month shearing, in particular, will be reduced by the use of cover comb shearing technology and hence these management policies with their associated advantages (Parker and Gray, 1989) will be adopted more readily.

To quantify the adoption rate of cover comb technology, two approaches were taken: first, cover comb sales were used as a proxy for the number of sheep shorn with a cover comb and, second, a nation-wide survey of large scale shearing contractors, who between them shore a considerable portion of the national flock, was undertaken. The findings from these two assessments are presented in this chapter.

## METHODS

The rate and extent of cover comb technology uptake was estimated from data provided by shearing contractors, Wools of New Zealand Wool Production Officers and cover comb manufacturers as described below. Useful information was also obtained from informal discussions with farmers and Mr R. Kidd (Wools of New Zealand Shearing Services Manager).

### Cover Comb Sales

Agrisales NZ Ltd, distributor of the Sunbeam cover comb, and Heiniger NZ Ltd, distributor of the Heiniger high country comb, provided confidential information on cover comb sales over time, as an indication of cover comb technology uptake. Agrisales provided annual cover comb sales figures from 1985/86 through to 1995/96 as a percentage of the conventional comb sales. Heiniger began manufacture of a cover comb in 1994, and provided cover comb sales figures as a percentage of total comb sales on a monthly basis from August 1994 to August 1996. There is insufficient sales information on the Chinese John Hand comb, only recently (1995) introduced to the market, to usefully predict the uptake of this brand of cover comb.

### Shearing Contractors Survey

A mail survey was sent to eight North Island and eight South Island shearing contractors in August 1996 (refer Appendix V). These contractors were selected by Mr R. Kidd, as being representative of the larger scale shearing contractors who shear most of New Zealand's flock. Collectively, the selected contractors shore over 10% of the national flock in the 1995/96 season.

Data was requested on the total number of sheep shorn, and the percentages shorn with a cover comb, Big 10, Sunbeam 9, Gould lifter and blades, for ewes, hoggets and lambs, in 1985/86, 1992/93 and 1995/96, as well as expectations for tallies in 2000/01. Information on the timing of cover comb shearing and the proportions of sheep shorn in winter and early spring was also requested. Shearing contractors were asked to describe problems experienced in encouraging farmers and shearers to use cover combs, opportunities and limitations for future use of the cover comb technology, and to indicate their strength of belief in relation to specific statements about cover combs and their use.

Information was requested on the use of Big 10 and Sunbeam 9 combs, and the Gould lifter, as these are used as alternatives to cover combs. Big 10 and Sunbeam 9 combs have fewer teeth than a conventional comb and therefore flatten the fleece less during shearing. These combs are still perceived by some to be winter combs, although unpublished research has shown they leave no more residual wool than conventional combs (Burnham, 1996, personal communication). Gould lifters are used with a cover comb and leave more residual wool than a cover comb only, and in this respect imitate the effect of blade shearing.

**Wool Production Officers Survey**

A questionnaire was sent to the eight Wools of New Zealand Wool Production Officers (WPOs) in August 1996, asking for their estimation of the timing of shearing and the number of sheep shorn with a cover comb in the 1995/96 season. General comments on cover comb technology uptake in their region of responsibility, and a description of the opportunities and limitations on the further uptake of cover comb technology, were also requested (Appendix V, questions 7 to 11).

## RESULTS AND DISCUSSION

Replies were received from all eight North Island shearing contractors, five of the eight South Island shearing contractors and the eight Wool Production Officers. Not all questions were completed by all contractors or Wool Production Officers.

### Cover Comb Sales

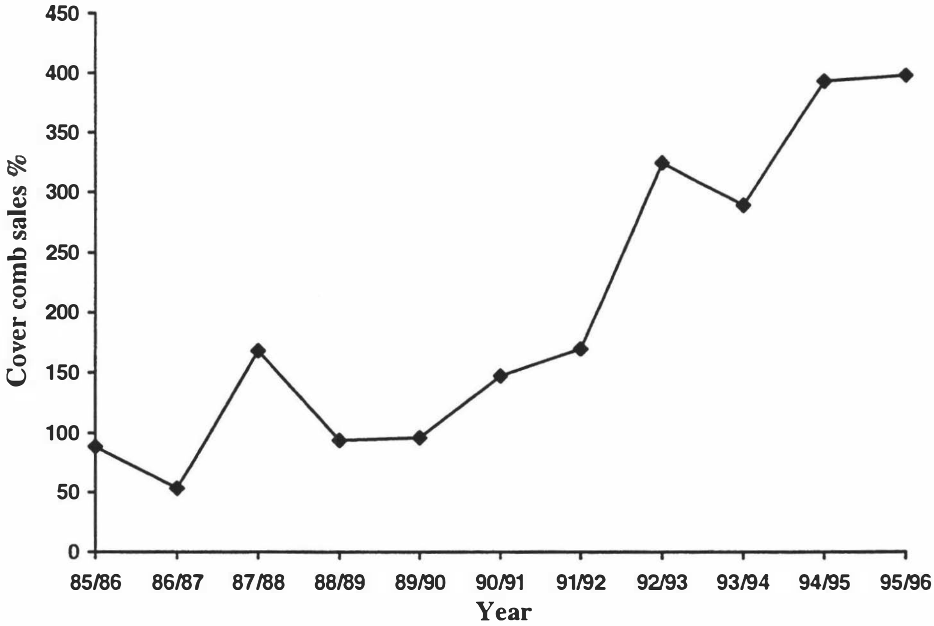
Sales of the Sunbeam cover comb measured by the increase in cover comb sales as a percentage of total comb sales, increased dramatically following the publication of the first research results in 1989, as shown in Table 3.1 (Note: total comb sales is the total number of conventional and cover combs sold). In order to preserve the confidentiality of sales data, the average proportion of cover combs sold during the 1985/86 to 1989/90 seasons is expressed as a base figure of 100, and the subsequent seasons are expressed relative to this. The number of publications and reports relating to the cover comb trials in each sales year is also included in Table 3.1, to illustrate the relationship between sales and the release of research findings.

**Table 3.1 : Cover comb sales as a percentage of conventional comb sales based on the average of the 1985/86 - 1989/90 seasons (base figure of 100) and the number of scientific publications on cover comb research.**

| Season | Sales percentage relative to base seasons | Number of publications and reports |
|---|---|---|
| **1985/86 - 1989/90** | 100 | 1 |
| **1990/91** | 147 | 1 |
| **1991/92** | 170 | 0 |
| **1992/93** | 325 | 1 |
| **1993/94** | 289 | 0 |
| **1994/95** | 393 | 4 |
| **1995/96** | 399 | 4 |

Figure 3.1 shows the increase in cover comb sales as a percentage of total comb sales data from 1985/86 to 1995/96. As for Table 3.1, the average proportion of cover combs sold during the 1985/86 to 1989/90 seasons is expressed as a base figure of 100, and the sales data are expressed relative to this.

Figure 3.1 : Cover comb sales as a percentage of total comb sales
(average of 1985/86 to 1989/90 seasons expressed as a base figure of 100).




As noted earlier, these figures reflect only Sunbeam's, with the ratio affected by sales of both cover combs and conventional comb types. Sunbeam was the only manufacturer of cover combs until the 1994/95 season when the Heiniger high country comb came onto the market. Had Sunbeam remained the sole supplier, the proportion of cover comb sales for the last two seasons would likely have been higher. As can be seen from Figure 3.1, cover comb sales as a percentage of total comb sales increased in 1989/90, after the publication of the first results from the Massey University research. The subsequent large increases appear to coincide with further research publications. The greatest increase in sales occurred between 1991/92 and 1992/93.

There was a strong relationship between the level of adoption as measured by cover comb sales and time ($\overline{R}^2 = 0.79$ for 1985/86 to 1995/96; $\overline{R}^2 = 0.88$ for 1989/90 to 1995/96). The uptake was still occurring in 1995/96, so the rate of future uptake and the ceiling level for the technology was not able to be predicted using this relationship.

The increase in cover comb sales was credited by Roger Locke, managing director of Agrisales NZ Ltd., to be due to Massey University research. His comment was "...and it is indeed interesting to note the quite significant uptake in the 1992/93 season which, I am sure, is directly attributable to the published research that was done by Professor Parker and his team which, coupled with the improvements already mentioned to the physical features of the Cover Comb, assisted in the uptake of their usage" (Locke, R., 1996, personal communication). The increased demand in cover combs prompted the Sunbeam Corporation Ltd to utilise new technology to improve the quality in the manufacture of their cover combs. These changes could have encouraged the continued use of the cover comb rather than prompted its initial uptake, as the greatest increase in cover comb use had already occurred prior to these improvements.

Heiniger's sales of the cover comb as a percentage of total comb sales, suggest that sales of cover combs in the 1995/96 season were greater than those in the 1994/95 season. In the 1995/96 season, over 50% of the comb sales in April, May and June were cover combs. Over 10% of sales from March through to September were cover combs. Heiniger estimates that cover comb sales in the North Island are increasing, being approximately 25% of total comb sales in 1995, and 35% of total comb sales in 1996. The growing share of cover comb sales, particularly in the North Island, suggests there is continuing interest in this shearing technology.

**Survey Results**

*Timing of Shearing with a Cover Comb*

Data were provided by eight contractors for 1992/93 (5 NI and 3 SI), twelve contractors for 1995/96 (7 NI and 5 SI) and estimates by ten contractors for 2000/01 (7 NI and 3 SI). The cover comb was not used by the contractor in Northland. Wool Production Officers also commented on the timing of cover comb shearing and their answers agreed with those of the contractors.

In 1992/93, four contractors shore ewes with a cover comb in the mid-winter months (pre-lamb shearing); by 1995/96 the period the cover comb was used for shearing had increased (May to August/September) for three of these contractors. Two contractors (one in each Island) in 1992/93 used a cover comb to shear ewes from May to September and expected to continue to do so. Both these contractors had been using cover combs for a number of years. The main month for shearing ewes with cover combs for one North Island contractor in 1992/93 and 1995/96 was March. Four contractors, two of whom were shearing with a cover comb in 1992/93 and two who were not, used a cover comb to shear ewes for 2, 3, 4 and 5 months in 1995/96. No figures were provided for 1992/93. Contractors expected the months of shearing with a cover comb to be the same in 2000/01 as for 1995/96.

The main months for shearing hoggets with a cover comb were from August to October, although 3 North Island contractors also shore hoggets with a cover comb in May. One North Island contractor had not shorn hoggets with a cover comb in 1992/93, but was using it for this purpose in 1995/96. Months for shearing hoggets with a cover comb were similar for both 1992/93 and 1995/96, and were expected to be the same in 2000/01.

Two South Island contractors shore lambs with a cover comb; one in 1992/93 and 1995/96 from February to April, the other in 1995/96 in November and February. The other contractors did not use a cover comb to shear lambs, and did not expect to do so in the future.

The main months of cover comb use have extended in the past five years, from the winter months for pre-lamb shearing, to the months of May to September. There has been an increase in the use of the cover comb for some second shearing of ewes in May, and for hogget shearing, particularly in August and September.

*Numbers of Sheep Shorn with a Cover Comb and First Year of Adoption*

The percentages of sheep shorn with a cover comb in 1992/93 and 1995/96, and the first year of cover comb adoption, are shown in Table 3.2. Contractors 1 to 7 are North Island contractors and 8 to 12 are South Island contractors. Only three contractors answered the question relating to 1985/86 tallies, the remainder did not choose to reply, had lost records or were not contracting at the time. There were nine replies for 1992/93, two of which included combined ewe and hogget figures, and twelve replies for 1995/96, four of which included combined ewe and hogget figures. Six contractors, three from each Island, provided estimates for 2000/01. One contractor provided figures for the percentages shorn with a cover comb, but not the numbers of sheep shorn. Actual numbers shorn by each contractor are not shown due to confidentiality of the data, but these ranged from 30,000 to 900,000 ewes and hoggets. The median number of sheep shorn in 1995/96 was 340,000.

**Table 3.2 : Percentages of ewe and hogget shearings with a cover comb in 1992/93 and 1995/96, and year of first shearing with a cover comb. Contractors 1-7 are in the North Island and 8-12 are in the South Island.**

| Contractor | First used[1] | Ewes | | Hoggets | | Ewes and Hoggets | |
|---|---|---|---|---|---|---|---|
| | | 1992/93 | 1995/96 | 1992/93 | 1995/96 | 1992/93 | 1995/96 |
| **1** | - | 0 | 0 | 0 | 0 | 0 | 0 |
| **2** | 1986 | 20 | 20 | 3 | 3 | 15.6 | 15.6 |
| **3** | 1990 | 21 | 19.4 | 0 | 22 | 17.4 | 19.8 |
| **4** | 1994 | - | - | - | - | 1 | 10 |
| **5** | 1990 | - | - | - | - | - | 25 |
| **6** | 1989 | 30 | 30 | 50 | 50 | 36 | 36.1 |
| **7** | 1990 | 2 | 7 | 1 | 10 | - | - |
| | | | | | | | |
| **8** | 1995 | 0 | 90 | 0 | 90 | 0 | 90 |
| **9** | 1960s | - | - | - | - | 90 | 90 |
| **10** | 1984 | 30 | 36[2] | 3 | 3 | 23.6 | 27.4 |
| **11** | 1993 | - | - | - | - | - | 50 |
| **12** | 1994 | - | 13[2] | - | 3[2] | - | 11.7 |

[1] One North Island contractor who did not supply data on numbers or percentages shorn, first shore with a cover comb in 1990.

[2] Gould lifter was also used. Two contractors also shore sheep with a lifter in 1995/96, with Contractor 10 shearing 3% of ewes with a lifter and Contractor 12 shearing 9.6% of ewes and 2% of hoggets with a lifter.

The Northland contractor (1) did not use a cover comb, although he had one client who asked for a Big 10 comb to be used. None of the other contractors used a Big 10 comb and none had shorn with a Sunbeam 9 comb or with blades.

The increased uptake of cover combs in recent years is shown by the fact that eight of the twelve contractors first used this type of comb after 1990. Four of these first used the cover comb in 1990, the remaining four between 1993 and 1995. Three contractors used a cover comb for the first time in the 1980's. The contractor who first used a cover comb in the 1960's was probably referring to a snow comb, which was a term for the original cover comb.

Only six contractors answered the question on shearing lambs with a cover comb. Five contractors had not shorn lambs with a cover comb nor anticipated having to do so in the future. One South Island contractor shore lambs using a cover comb. The percentage of lambs shorn with a cover comb was 0.05, 2.5, 5 and 10 percent for 1985/86, 1992/93, 1995/96 and anticipated for 2000/01, respectively.

Only four contractors were shearing in 1985/86; two did not shear with a cover comb at this time. One of the contractors shearing with a cover comb at this time was from the North Island, the other from the South Island. The percentage of ewes cover comb-shorn by the North Island contractor increased fourfold between 1985/86 and 1992/93, from 5% to 20%, but remained at 30% for the South Island contractor. Hoggets shorn by the North Island contractor increased from 0% to 3% in this period, and were static at 3% for the South Island contractor. The combined effect of fewer contractors shearing with a cover comb and fewer sheep being shorn with a cover comb suggests that the use of the cover comb prior to the research in 1989 and subsequently was small, particularly in the North Island.

Most contractors expected either no increase or a small increase in the percentages shorn with a cover comb in 2000/01. Two South Island contractors expected an increase in the percentage of ewes shorn with the Gould lifter; one predicted a corresponding 12% decrease in the use of the cover comb alone, the other a 2% increase in ewes shorn with a cover comb and a 10.5% increase in ewes shorn with the lifter. The latter contractor also expected a 3% increase in hoggets shorn with a cover comb, and an 8% increase in hoggets shorn with a lifter by 2000/01. As the Gould lifter is used with a cover comb, total adoption of the technology is forecasted by these contractors to increase.

The proportions of ewes and hoggets shorn with a cover comb, weighted by the numbers shorn by the contractors for 1992/93 and 1995/96, showed the number of cover comb shearings were 21.5% for 1992/93 and 24.9% (26% excluding those with no 1992/93 figures) for 1995/96, an increase of 3.5%. These figures cannot be interpreted as a national trend as the sample is not representative of all sheep shorn in

New Zealand, but they do suggest that the technology is being more widely used now than five years ago.

The numbers of ewe and hogget shearings with a cover comb in 1992/93 and 1995/96, for the North Island, South Island and New Zealand are shown in Appendix VI. The New Zealand percentages are based on the total numbers shorn and the numbers shorn by cover comb in each Island. The combined figures show more ewes and hoggets shorn with a cover comb than the individual data, because contractors who provided combined figures only, shore a greater percentage with a cover comb than those who provided individual data for sheep age classes. Results suggest 26.6% and 29.8% of ewes and hoggets shearings were with a cover comb in 1992/93 and 1995/96, respectively (combined figures). This equates to over sixteen million sheep, if it is assumed that sheep shorn twice in a year are shorn with a cover comb for only one of these shearings.

The estimates by five WPOs' of the numbers of ewes, hoggets and lambs shorn in total, and with a cover comb, in 1995/96 in their region are presented in Table 3.3. No figures were received for the Canterbury/Nelson/Marlborough, Aorangi and Southland/West Otago regions. WPOs based their percentages on numbers of sheep shorn in their region, whereas contractors would have based their percentages on numbers of sheep they shore i.e. shearings. WPOs' estimates of the percentage of sheep shorn with a cover comb are likely to be greater than the percentage of shearings with a cover comb, because some sheep are shorn twice in a year.

**Table 3.3 : Wool Production Officers' estimates of the regional populations of sheep and the percentage of ewes, hoggets and lambs shorn with a cover comb. (Numbers are in thousands).**

| Region | Total number shorn ('000) | % Cover comb shorn | No. cover comb shorn ('000) |
|---|---|---|---|
| **Northland/Auckland/Waikato/Bay of Plenty** | | | |
| Ewes | 6000 | 0.5 | 30 |
| Hoggets | - | 5.0 | - |
| Lambs | - | 0 | 0 |
| **Hawkes Bay/Poverty Bay** | | | |
| Ewes | 7000 | 21.4 | 1500 |
| Hoggets | 1800 | 38.9 | 700 |
| Lambs | 7000 | 0 | 0 |
| **Taranaki/Manawatu/Wanganui** | | | |
| Ewes | 9000 | 5.6 | 500 |
| Hoggets | 2500 | 20.0 | 500 |
| Lambs | 7000 | 0 | 0 |
| **Wairarapa/Tararua** | | | |
| Ewes | 2500 | 35.0 | 875 |
| Hoggets | 1000 | 85.0 | 850 |
| Lambs | 1500 | 2.0 | 30 |
| **Otago** | | | |
| Ewes | 8000 | 47.5 | 3800 |
| Hoggets | 3000 | 33.3 | 1000 |
| Lambs | 1500 | 33.3 | 500 |

The WPO's estimates of the number of sheep in their regions differed from the official estimates (Appendix VII). The WPOs' survey suggests between two and three million ewes, and two to two and a half million hoggets were cover comb shorn in the North Island in 1995/96. The South Island number is likely to be higher, because over 2,500,000 ewes, and 750,000 hoggets were shorn in Otago alone. In some instances, estimates of the percentage of sheep shorn with a cover comb varied between contractors and WPOs in the same area. Contractors' estimates of the proportions of hoggets shorn by cover comb for 1995/96 ranged from 3 to 90%, with a median of

10% (excluding the Northland contractor), and tended to be more conservative than those made by the Wool Production Officers (Table 3.3).

Overall, the cover comb sales and survey results show that the uptake of cover comb technology over the last few years has been rapid, but in the next few years it is likely to slow down and level off. Both the sales figures and the contractors survey suggest the greatest increase in the uptake of cover comb technology uptake occurred between 1990 and 1992/93, with the rate of increase dropping to between 3 and 5% between 1992/93 and 1995/96.

The results (allowing for the fact that some ewes are shorn twice) agree with those obtained in a national survey conducted by Rauniyar and Parker in 1996, which showed 32% of farmers (79 respondents) used a cover comb for ewe shearing. The greatest increase is likely to have been in the North Island where over 16% of ewe shearings are now by cover comb, compared to very few prior to the research. As could be expected from climatic conditions, a larger proportion of ewes were shorn with a cover comb in the South Island (over 29%, and possibly up to 46%) than the North Island, although the actual increase is not expected to have been as great because of the earlier adoption of the cover comb in the South Island. Combined, ewe and hogget data show a 5% increase in cover comb shearings between 1992/93 and 1995/96 in the North Island, but only a 0.5% increase in the South Island during this period.

Hogget shearing results in this study are intermediate between those found by Rauniyar and Parker (1996), and Morris, S. (1996, personal communication). For the surveys reported here, 11% of hoggets were estimated to be shorn with a cover comb in 1995/95; the majority of these were in the North Island (16.7% compared to 5.8%). Rauniyar and Parker (1996), found 19% (77 respondents) of farmers shore hoggets with a cover comb, while in a telephone survey of 14 shearing contractors in the Taranaki, Wanganui, Manawatu and Wairarapa districts estimated proportion of hoggets shorn with a cover comb was only 7.5% of the total shorn. These lower western North Island hoggets were mainly shorn in August and some in September

(Morris, S., 1996, personal communication) Morris (1996) established that most farmers hogget shearing in October did not believe they needed to use a cover comb, as feed was plentiful at that time, although losses were still acknowledged to be high in some cases. Research into, and publication of information relating to, the advantages of a cover comb for hogget and lamb shearing may result in a greater uptake of the technology for these classes of sheep.

Extension activities in the North Island by the WPOs appear to have been greater than in the South Island. For example, there were a greater number of field days at which the cover comb was mentioned in the North Island than in the South Island: 35 field days held by two North Island WPOs compared to 27 South Island field days held by the four South Island WPOs. Two North Island WPOs did not answer this question. North Island WPOs also spent more time on cover comb-related activities than South Island WPOs. Cover combs have been more widely used in the South Island in the past, and further extension activities seem to have been considered largely unnecessary. This lower emphasis on extension activities, alongside the fact that the technology was already established in the South Island, could have contributed to the greater rate of technology uptake in the North Island than the South Island. Fewer hoggets are also likely to be shorn in the South Island in August and September, the months the cover comb is primarily used for hogget shearing.

Inclement weather in 1992, combined with the publicity given to the research results on the benefits of using cover comb technology, may have contributed to the rapid increase in the use of the cover comb in 1992/93. One South Island contractor's comment was "Up until 1992 nearly 99% of our clients shore with conventional combs. After suffering large losses in the snow and a newsletter that I sent out regarding cover combs, it turned around to 98% cover comb within a year".
The contractors surveyed were large scale operators who tended to keep good records (Kidd, R.,1996, personal communication). It is possible that some smaller contractors may be more conservative, and less inclined to encourage their clients to shear with a cover comb or to promote cover comb technology. As a result they may shear fewer sheep with a cover comb, or prefer to use the less effective Big 10 or Sunbeam 9 comb

as a winter comb. If this were true, the estimates of cover comb uptake provided here would be inflated.

*Proportion of Sheep Shorn in Winter and Cover Comb Use*

Six North Island and five South Island contractors who shore with a cover comb replied to the questions relating to the proportion of clients asking for sheep to be shorn between May and September (Table 3.4). The results from both the contractors survey and the WPOs survey suggest that 90% of sheep shorn in winter and early spring (May to September), predominantly ewes, are now shorn with a cover comb. The percentage varied between contractors and regions, however more sheep are shorn with a cover comb in the South Island than the North Island over this period. This is supported by Mr I. Wright, General Manager of Heiniger NZ Ltd, who estimated 35% of cover comb sales were in the North Island and 65% in the South Island in 1996.

**Table 3.4 : Percentage of clients asking for sheep to be shorn between May and September, and the percentage of these clients requesting that the sheep be shorn with a cover comb.**

| | North Island | | South Island | | National | |
|---|---|---|---|---|---|---|
| | **Total** | **Cover comb** | **Total** | **Cover comb** | **Total** | **Cover comb** |
| **Responses** | 5 | 6 | 5 | 5 | 10 | 11 |
| **Mean** | 53.0 | 88.0 | 58.4 | 95.2 | 55.7 | 91.3 |
| **Median** | 55 | 89 | 50 | 95.2 | 52 | 91.3 |
| **Standard Deviation** | 35.1 | 11.7 | 24.0 | 4.8 | 28.5 | 9.6 |
| **Minimum** | 15 | 70 | 27 | 90 | 15 | 70 |
| **Maximum** | 90 | 100 | 85 | 100 | 90 | 100 |

Results for the Northland contractor who did not use a cover comb are not included. Ninety percent of his clients asked for sheep to be shorn in winter.

Almost all sheep now shorn with a cover comb were previously shorn with a conventional comb, with the exception of a South Island contractor who previously shore 10% of the sheep with blades.

Eleven of the twelve contractors using the winter comb reported an increase in the numbers of sheep being shorn in the winter-early spring period (May to September) in the past five years. Three contractors from each Island specified the proportional increase in sheep shorn in this period since the 1992/93 season. Results were highly variable, being 20, 10 and 300 percent for the North Island contractors and 30, 20 and 6 percent for the South Island contractors.

This increase in numbers of sheep being shorn in the winter-early spring period (May to September) over the last five years could be due to changes in shearing policies to once yearly pre-lamb, or eight monthly with every third shearing occurring in this period. The downturn in wool prices may have contributed to farmers changing to these policies from a second shearing policy, reducing shearing costs, allowing a more even spread of labour and producing better length wool (Parker and Gray, 1989). The availability of cover comb technology to reduce the risks associated with shearing in this period may have contributed to the decision to change policies. Increases in numbers of sheep shorn in this period could also be due to changes in shearing dates rather than policy, perhaps allowing a better spread of labour.

*Opinion Data*

Contractors opinions' on a number of statements related to the use of the cover comb are summarised in Table 3.5.

**Table 3.5 : Shearing contractors beliefs about attributes of the cover comb technology. Figures in brackets show the response for each Island e.g. (6,1) means 6 North Island and 1 South Island contractor.**

| Statement | Not Sure | Strongly Disagree | Disagree | Agree | Strongly Agree |
|---|---|---|---|---|---|
| **Reduce losses**[1] | 0 | 0 | 0 | 7 (6,1) | 6 (2,4) |
| **Save feed**[2] | 0 | 0 | 0 | 8 (5,3) | 4 (2,2) |
| **Easier to shear with**[3] | 1 (0,1) | 0 | 7 (6,1) | 4 (2,2) | 1 (0,1) |
| **Farmers know difference**[4] | 2 (2,0) | 1 (0,1) | 4 (3,1) | 5 (2,3) | 0 |
| **Big 10, Super 9 as effective**[5] | 2 (2,0) | 7 (3,4) | 4 (3,1) | 0 | 0 |
| **Shearers paid same**[6] | 0 | 6 (5,1) | 7 (3,4) | 0 | 0 |
| **Information available**[7] | 2 (1,1) | 1 (0,1) | 3 (2,1) | 7 (5,2) | 0 |
| **More use in cold/wet season**[8] | 1 (1,0) | 0 | 3 (3,0) | 7 (3,4) | 1 (1,0) |

[1]Winter combs reduce sheep losses after shearing.

[2]Using the winter comb enables farmers to save feed during the first 3 weeks after shearing.

[3]Winter combs are easier to shear with than conventional combs.

[4]Farmers know the difference between types of combs for winter shearing. (e.g. Big 10, Sunbeam 9, cover comb, high country comb)

[5]Big 10 and Sunbeam 9 combs are as effective as the Sunbeam cover comb, the Heiniger high country comb and the Chinese John Hand comb for winter shearing.

[6]Shearers should be paid the same for using winter combs as conventional combs.

[7]Information on the effect of the winter comb on sheep production and losses is easy to obtain.

[8]The winter comb is more widely used if the winter-spring is colder and/or wetter than normal.

Opinions on the availability of information on the advantages of cover comb shearing were mixed, with seven contractors agreeing the information was readily available and four disagreeing. These results suggest further extension effort to promote the benefits of cover comb shearing may be advantageous in some areas.

All contractors believed the use of a cover comb for shearing reduced sheep losses and saved feed in the first three weeks after shearing. These findings were associated with the 1989, 1990 and 1992 cover comb trials, which suggested they had all read or heard of the trial results at some time. Publication of the research trial results was widespread nationally. An article on the benefits of blade shearing and cover comb shearing appeared in at least 21 newspapers throughout New Zealand after the 1995 calorimetry trial. Information on coverage after the earlier trials is unknown. This may mean that information on the benefits of cover comb shearing was widely available at the time of the trials, but continued access to this information may be a problem in some areas.

None of the contractors surveyed believed that Big 10 or Super 9 combs were as effective as winter combs for winter shearing. Two North Island contractors were unsure, the remaining eleven contractors all either agreed or strongly disagreed. The contractors surveyed were all large scale contractors. It is possible some smaller scale contractors may be more conventional and continue to use these as winter combs, particularly in the North Island where the use of winter combs in the past has been less widespread, and there may be less information on, or experience of, the various winter combs. These contractors may also be less inclined to change to cover combs, because they considered them to be more difficult to shear with. Opinions were divided as to whether farmers knew the difference between combs for winter shearing.

All South Island contractors and half of the North Island contractors believed the cover comb would be more widely used if the winter or early spring was colder or wetter than usual. This may be a reflection of the climate in their district, with the cover comb being more widely used in areas where climatic extremes are more likely to occur.

*Opportunities for Further Use of a Cover Comb*

Eight contractors could see further opportunities for cover comb use in their areas, and five could not. Opportunities highlighted related to: pre-lamb shearing of ewes; earlier hogget shearing; reduction in sheep feed intake after shearing; reduction of sheep losses; spreading the work flow in winter; and the shearing of ewes and hoggets at short notice for live shipment (i.e. the period from shearing to the minimum pre-shipment wool length could be reduced).

Wool Production Officers also commented on this question. Further comments to those above included using the cover comb for: second shorn ewes post-tupping in May; shearing ewes with lambs at foot in October; shearing 8 months shorn ewes in March; lamb shearing; and use with lifters to replace blade shearing.

*Potential for Further Uptake of Cover Combs*

The rapid uptake of cover comb technology to date (Table 3.1) appears to have involved the adoption of the cover comb for shearing in the May to September period, with most sheep shorn during this period being shorn with a cover comb. Although there is potential for some further uptake of the cover comb for shearing in this period, the survey responses suggest uptake is probably close to the ceiling level of adoption. Most cover comb technology uptake for shearing in the winter-early spring has been for sheep previously shorn with a conventional comb during this period, and has required little or no change to other farm management practices. The adoption of a technology that involves policy changes is likely to be slower and less widespread than one which can easily be adopted into the current system. Further uptake of cover comb technology for ewe shearing in the winter and early spring is likely to be associated with increases in numbers of sheep being shorn in winter, brought about by changes in shearing policies or shearing dates.

Some second shorn ewes in May are being shorn with a cover comb, and there is potential for further uptake of cover comb use for second shearing of ewes in May, October and November. Cover comb use for ewe shearing in March was suggested; this was also the main month of ewe shearing with a cover comb for one contractor. The use of a cover comb for shearing at this time may provide feed-saving advantages in summer-dry regions. Unless there is a feed shortage it can be questioned whether this is practical, as the increased appetite of ewes shorn pre-tupping has a flushing effect which could be reduced by shearing with a cover comb.

The cover comb is predominantly used for hogget shearing in August and September, although there is wide variation between contractors. There is potential for further hogget shearing with a cover comb, particularly in October. The opportunity for further use of the cover comb for hogget shearing was recognised by more WPOs than contractors; only one contractor mentioned the opportunity for an increase in the use of the cover comb for hogget shearing. This contractor also expected a greater increase in cover comb use for hogget shearing in the future than the other contractors who expected little or no increase. As previously mentioned, farmers are also using a cover comb to shear hoggets for sale purposes, and there may be an increase in its use for this reason in the future. Further research and extension on the benefits of the cover comb for hogget shearing may be beneficial, and lead to an increase in cover comb use for hogget shearing in the future.

Few lambs were reported as being shorn with a cover comb. Only one contractor surveyed shore lambs with a cover comb; the number shorn with a cover comb had increased over time and was expected to continue to do so. Most WPOs saw opportunities for further shearing of lambs with a cover comb. Lambs would be more vulnerable than adult sheep to adverse weather conditions, which can occur at any time of the year. A North Island farmer who recently lost a large number of lambs post-shearing, after unseasonable weather in January, is now seriously considering using a cover comb for lamb shearing. This lamb loss could result in a financial loss of $8000 this year, which would have easily covered the extra cost of cover comb shearing for a considerable time. There are also selling advantages, as previously mentioned, to shearing lambs with a cover comb.

The potential for further use of a cover comb on hoggets and lambs for live shipment was recognised by both contractors and WPOs in regions supplying the live sheep trade. There is also scope for cover comb shearing, either with or without a lifter, to replace blade shearing in the South Island.

*Problems encouraging Farmers and Shearers to use a Cover Comb*

Eight contractors encouraged their clients to winter shear and four did not. Most did not have problems encouraging their clients to use a cover comb. Problems that did occur with cover combs were: wet conditions and getting sheep dry; the extra cost of using cover combs; and getting farmers to try something new in preference to the traditional way of doing things.

Problems encountered in getting shearers to use cover combs were the extra cost of purchasing cover combs and the reasonably new cutters which are required when using cover combs. These problems were resolved through the extra earnings per sheep for cover comb compared to conventional comb shearing (usually an extra $8.00 or $8.50 per 100 sheep). The opinion data (Table 3.5) showed all contractors agreed or strongly agreed that this extra cost for cover comb shearing over conventional shearing was justified.

The shape of the cover comb was a problem for some shearers initially, however recent improvements to the comb design have resolved this problem (Kidd, R., 1996, personal communication). The spline drive has made shearing with cover combs safer. Educating the shearers in cover comb use was necessary initially. Mud at shearing can be a problem in some areas with cover comb use.

*Limitations on Further Use of the Cover Comb*

Two contractors saw factors preventing more widespread use of cover combs in their local areas, and ten did not. One contractor mentioned the weather, and mud in the "stronger" hill country, and the other noted that contractors in his area tended to shy away from the use of cover combs.

Observations made by WPOs on factors that may prevent further adoption or reduce the rate of cover comb adoption included the extra cost of combs and shearing, lack of shearer acceptance, lack of knowledge of the advantages for hoggets and lambs, ridges left after shearing for stud stock, availability of combs, and concerns about pelt quality and hamstring cuts in lambs.

Some shearers find the cover comb difficult to use. Mr R. Kidd and some contractors suggested that this problem can be overcome by training shearers in the set up and use of the cover comb. Shearers more familiar with the use of the cover comb often found it easier to use than a conventional comb, due to fewer teeth allowing easier entry into the fleece. The opinion data support this finding, with some contractors finding the cover comb easier to use than a conventional comb. Those who believed the cover comb is easier to shear with were predominantly from the South Island where more sheep are cover comb-shorn, and sheep are usually bigger and probably in better condition at shearing.

Availability of cover combs has been a problem in recent years. The upgrading of Sunbeam's manufacturing technology and the entry into the market of the Heiniger High Country Comb and the Chinese John Hand Comb should resolve this problem in the future. The rapid increase in cover comb shearing technology uptake could have contributed to the demand for cover combs exceeding supply over this period.

The cost of purchasing the cover combs and the reasonably new cutters required for their use discouraged shearers from using cover combs. As mentioned, the extra price paid for shearing with a cover comb has resolved this problem from the shearers' perspective, however the extra cost deters some farmers from using a cover comb for shearing. A clearer understanding of the financial advantages to farmers of using a cover comb may help alleviate their concerns.

*General Comments on Cover Comb Uptake*

The WPOs commented generally on the uptake of cover comb shearing in their regions, as outlined below. These comments reinforce the findings previously mentioned.

The cover comb has been used since the 1970's, but the adoption of cover comb technology was very low until the last five years when rapid uptake occurred over most of the country, especially in the North Island. In Otago and Southland particularly, the cover comb has been used for some years due to the colder and more variable weather conditions, and the greater popularity of pre-lamb shearing than in the North Island. Nevertheless, the Otago WPO reported a steady increase in cover comb use over the last five years, even though it has been used in this area for some years. The WPO for Southland/West Otago noted that cover combs are now being replaced by "risers" for winter shearing, and estimated that 10% of winter shorn sheep are now shorn with cover combs and 90% with risers.

The cover comb is now being used extensively for winter shearing of ewes and some hogget shearing, with most winter-shorn sheep being shorn with a cover comb. Initial use was for pre-lamb shearing, however the Hawkes Bay WPO noted that large numbers of May second-shear ewes are now being shorn with a cover comb. The Otago WPO reported more farmers now using a cover comb to shear lambs in February. He also noted that farmers accredited to the Wools of New Zealand Fernmark programme and the Wrightson's Woolcare programme are required to use the cover comb for winter shearing, which has contributed to its increased use in the last two years.

The Hawkes Bay WPO noted some interest in shearing lambs at weaning with a cover comb; this was being held back by concerns about pelt quality and hamstring cuts. The Wairarapa WPO mentioned some ewes were still being shorn with Big 10 or Super 9 combs which are still perceived by some shearers and farmers to be as effective as cover combs. The opinion data showed that the "large scale" contractors all disagreed that these combs were as effective as cover combs, suggesting this problem may relate only to some smaller or more conservative contractors.

WPOs were also asked to estimate the reduction in losses in adverse weather following shearing with a cover comb compared to a conventional comb. The WPO for Manawatu/Wanganui/Taranaki estimated that losses of 20 to 30% for hoggets or lambs could be reduced to 2 to 3%, and losses of 5 to 10% for ewes could be reduced to about 1% if shearing with a cover comb was followed by a severe storm. In Otago, shearing contractors estimated losses were reduced by 10 to 30%. In Southland, no estimate was able to be made as almost no one winter shears with conventional combs.

**Other Reasons for Uptake of Cover Comb Technology**

The survey results and informal discussions with farmers identified reasons for cover comb shearing other than those for which it was designed. In most instances, sales advantages were afforded by shearing with a cover comb, the extra wool left on the sheep and the fewer cuts enabling sheep to be sold at, or soon after, shearing rather than having to wait for two weeks for wool to regrow.

As previously mentioned, sheep being sent to the feedlot for live shipment can be shorn with a cover comb and sent at short notice. A farmer observed that "a lot" of hoggets are cutting their two-tooth teeth around the time of hogget shearing. For this reason some farmers are shearing hoggets with a cover comb, allowing them to be sent to the works immediately after shearing and prior to cutting their two-tooth teeth, therefore receiving a better price. The comment was made that the perceived increased intake after shearing often saw ewe hoggets go overfat, and sale at shearing avoided this. Lambs are also shorn with a cover comb to enable them to be sold at, or soon after shearing.

An instance was also cited of 5 year old cast-for-age ewes being shorn with a cover comb, with the slightly longer fleece on the ewes helping to attract a better price at sale time. Another advantage was that sheep could be effectively dipped at shearing, if shorn with a cover comb. Many of these reasons for cover comb use also have labour-saving implications with work being done while the sheep are at the yards for shearing, so reducing the need to bring sheep back to the yards at a later date.

The downturn in wool prices has meant some meat processing works now consider the wool on unshorn lamb pelts to be a liability, and at least one works is considering offering a premium on shorn lambs. A length of approximately 10 days wool growth, or the amount left by a cover comb, is considered to be ideal. There is expected to be some farmer resistance to this proposal, however if this does become a reality there may be an increase in cover comb use, with farmers shearing lambs with a cover comb before sending them to the works.

## CONCLUSION

The adoption of cover comb shearing has been rapid over the past few years. The greatest increase in uptake was between 1991/92 and 1992/93, and the rate of uptake has slowed and started to level off since 1994/95, suggesting a ceiling level of uptake is being approached. This increase in the uptake of the technology occurred at the time of the publication of the initial research trial results, and can be largely credited to the research trials and related extension. The cover comb is widely used in the South Island, however there has been increasing interest in its use in the North Island in recent years. In the lower South Island, in particular, the cover comb is being used with a lifter to leave even more wool on the sheep after shearing.

Most winter- and early spring- (May to September) shorn sheep are now shorn with a cover comb. These are predominantly pre-lamb shorn ewes, and August- and September- shorn hoggets. There is some use of the cover comb for second shear ewes in May, and for October-shorn hoggets, and there is potential to increase the numbers of ewes and hoggets shorn at these times with a cover comb. More sheep are also now being shorn in the winter and early spring, which would have contributed to the increase in cover comb use. Few lambs are shorn with a cover comb, and there is potential for this to increase.

The most obvious advantage of using a cover comb for shearing is the reduction in sheep losses, although feed savings are now being cited as an important reason for cover comb use. The cover comb is also being used for reasons other than that for which it was designed. The ability to sell cover comb shorn- sheep to the works or for live shipment at, or soon after, shearing has financial and labour advantages.

The research results and recent extension have had a large impact on the recent increase in the uptake of the cover comb, by quantifying and demonstrating the advantages of the technology. It is unlikely that this uptake would have occurred without that stimulus, particularly in the North Island.

In summary, it proved difficult to obtain the data necessary to quantify the pattern and level of adoption of cover comb technology. Taken together, the contractor and WPO survey results, and the pattern of cover comb sales, indicated a sharp rise in the use of technology following the publication of research findings. In the next chapter the estimates of the percentage of sheep shorn with a cover comb weighted by the numbers shorn will be used to calculate the numbers of sheep shorn with a cover comb over time, in order to calculate net benefits from cover comb shearing.

# CHAPTER FOUR

# MODEL DEVELOPMENT AND APPLICATIONS

## INTRODUCTION

Models represent the real world, albeit in a simplified manner, by simulating the key features of the system under study (Spedding, 1988). They are especially useful where it is impractical or impossible to carry out a research trial, or in situations where conducting a trial would disturb the system being studied to the extent that artificial results are obtained (Doyle, 1990). Modelling can often produce results comparatively quickly and inexpensively.

Organisations involved in research or research funding, including Wools of New Zealand, are becoming increasingly interested in ways to effectively evaluate potential research projects in order to optimise the benefits from their research funds. This study, and other similar studies (Dick *et al.*, 1967; Marsden *et al.*, 1980; Scobie and Eveleens, 1986; Bezar, 1993; Ralph, 1993) may be useful to agricultural research funding organisations because they demonstrate the financial returns to on-farm agricultural research funds, and as such can then be used to justify or refute further investment in this area.

A model for research evaluation would be particularly useful if it could be applied *ex ante* by research funders to help optimise the allocation of research funds. The real world alternative is to carry out all the trials being evaluated, and assess which would be the most worthwhile: an unrealistic scenario.

A cost-benefit analysis model has been developed to estimate returns to Wools of New Zealand investment in cover comb technology development, research and extension. While cost-benefit analysis has its limitations, it can: be used both *ex post* and *ex ante*; be applied at a project level; assist in the identification and gathering of information required for project appraisal; and be readily understood by all interested parties

(Norton and Davis, 1981; Bennett, 1993). These advantages make it particularly applicable to this study.

Assumptions are usually required for cost-benefit analysis. A sensitivity analysis can be applied to test the likely outcomes from changing the uncertain variables, in order to identify those that have the greatest impact. In research evaluation, technology uptake often has a large impact on the return to research (Marsden *et al.*, 1980; Davis *et al.*, 1987; Contant and Bottomley, 1988). Some of the uncertainties can also be minimised by keeping assumptions conservative; high returns found while using conservative estimates suggest a project is worthwhile. For these reasons both conservative estimates and sensitivity analysis were applied to this cover comb study.

Wools of New Zealand are accountable to the New Zealand wool industry and New Zealand sheep farmers for their funding. The downturn in wool prices over recent years may have contributed to questions being asked about what this funding is being spent on (Cresswell, 1996), and whether Wools of New Zealand investment in research is justified (Clarke, 1996). Government-funded research organisations are also expected to attract more research funding from outside organisations, leading to further pressure on industry organisations like Wools of New Zealand to contribute more towards sheep-related research.

The cover comb is an example of a discrete, relatively simple technology, where development, research evaluation and extension have been reasonably well documented. The development costs for the technology were primarily incurred by Sunbeam, and some of the research and extension costs were funded by an industry organisation (Wools of New Zealand). The framework of a model developed for the *ex post* cost-benefit analysis of cover comb shearing technology, will provide a basis for developing a more generalised *ex ante* cost-benefit model of on-farm research and development to assist organisations such as Wools of New Zealand in future decision making.

A model was developed using spreadsheet templates (Microsoft Excel) to calculate the net present value (NPV), the internal rate of return (IRR) and the benefit-cost ratio (BCR) to investment in research, development and extension of cover comb technology. A sensitivity analysis was conducted using this base model. The model includes some features which are not applicable to the cover comb study, but will be able to be adapted for *ex ante* cost-benefit analysis of other types of on-farm research and development. The development and application of this model are presented in this Chapter.

## METHODS

Figure 4.1 demonstrates the flow of information in the cover comb technology study. The sources of information, the design and the calculations performed are described in the following sections.

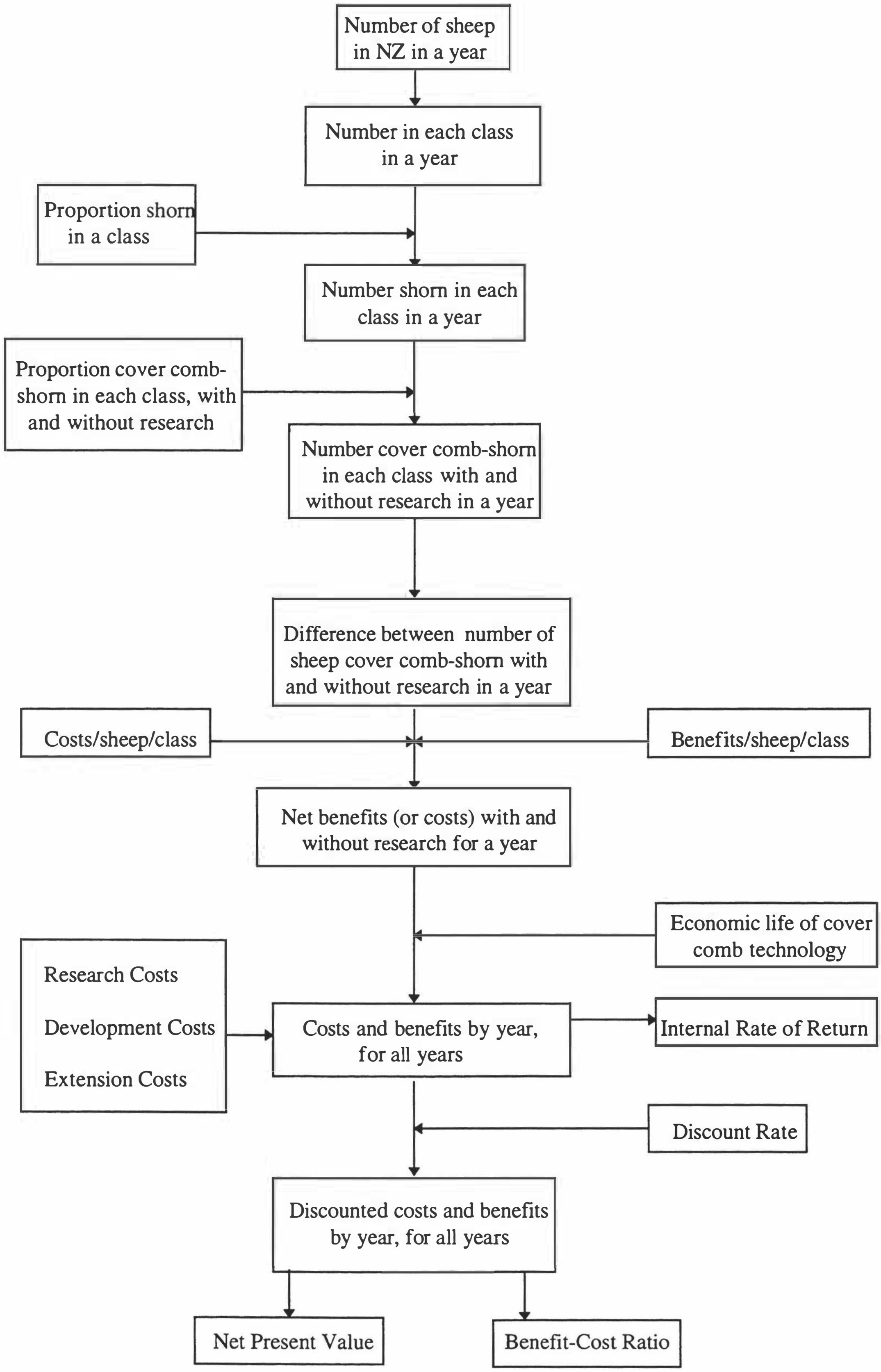



Figure 4.1 : Flow of information in the cover comb technology study.

**Sources of Input Information in the Investment Return Spreadsheet**

Figure 4.2 shows the sources, and flow of information in the model. The components are described later in this Chapter.

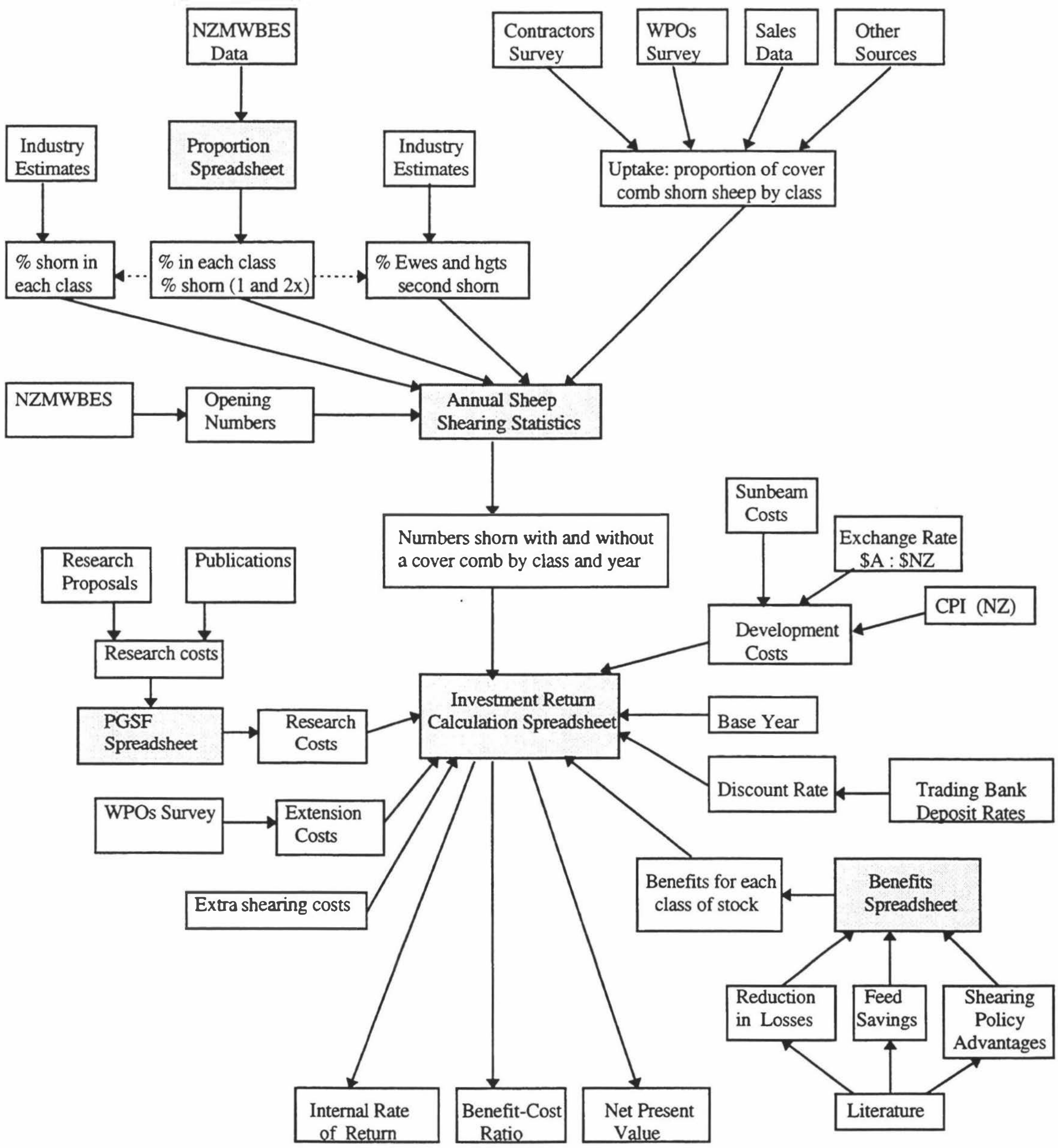



Figure 4.2 : A map of sources and flow of information in the cover comb technology study.

*Research Costs*

The calculation and timing of the research costs have been discussed in Chapter 2. These costs were incurred between 1989 and 1995 and came to $304,131 in 1996 New Zealand dollars. The timing of these costs is summarised in Table 2.3.

*Development Costs*

The development costs are detailed in Chapter 2. These costs were incurred by Sunbeam and are equivalent in 1996 dollars to NZ$152,711 being spent in 1972, NZ$155,172 in 1973 and NZ$248,715 in 1995; a total of NZ$556,598.

*Extension Costs*

The extension costs have been outlined in Chapter 2. These costs relate to the WONZ Wool Production Officers' extension costs between 1991 and 1996, and were estimated at NZ$10,000 per year; a total of NZ$60,000.

*Technology Uptake*

The results of the surveys of shearing contractors and Wool Production Officers, and other information on the uptake of cover comb technology, including the reasons for this uptake, have been discussed in Chapter 3. The results indicate that uptake of the cover comb has been rapid since the publication of the Massey University research results. Conservative estimates of the technology uptake to 1995/96 and the likely future uptake to a ceiling level have been based on these results. These estimates have been discussed with people working in the shearing industry to confirm they are realistic. Sensitivity analyses were also conducted to compare the effect of two different technology uptakes on the net benefits derived from the cover comb. In assessing the returns to research and extension it is the difference between the numbers cover comb-shorn with, and without, the research and extension that is used in calculating the benefits.

The adoption uptake with research has been kept at the same level, however two levels of uptake without research were used. In presenting these results, the lower level of uptake without research (and therefore higher uptake due to research and extension) is referred to as adoption rate 1 (AR1), the second adoption rate without research as AR2. It was assumed a ceiling level without research had been reached as the technology had been available for 15 to 20 years prior to the research and extension. Heavy snowfalls in the 1992/93 season may have further increased the use of the technology in the South Island and the adoption levels allow for this. Table 4.1 summarises the percentage of sheep cover comb-shorn, with and without the research and extension, over time i.e. adoption rates.

**Table 4.1 : Percentage of sheep in each class cover comb-shorn with, and without, research and extension.**

| Class Year | 1989 | 1992 | 1995 | 2000+ |
|---|---|---|---|---|
| **Ewes** | | | | |
| **With Research** | 15 | 29 | 33 | 35 |
| **Without Research (1)** | 15 | 18 | 20 | 20 |
| **Without Research (2)** | 15 | 20 | 25 | 25 |
| **Ewe Hoggets** | | | | |
| **With Research** | 1 | 7 | 11 | 15 |
| **Without Research (1)** | 1 | 2.5 | 3 | 3 |
| **Without Research (2)** | 1 | 3 | 5 | 5 |
| **Other Sheep** | | | | |
| **With Research** | 3 | 7 | 10 | 10 |
| **Without Research (1)** | 3 | 4 | 5 | 5 |
| **Without Research (2)** | 3 | 4 | 5 | 5 |
| **Lambs** | | | | |
| **With Research** | 0 | 0 | .1 | 1 |
| **Without Research (1)** | 0 | 0 | 0 | 0 |
| **Without Research (2)** | 0 | 0 | .1 | 1 |

**Calculation of Benefits**

The measurable benefits associated with cover comb shearing identified in this study came from three areas: a reduction in sheep losses due to the use of cover combs for shearing rather than conventional combs; a reduction in costs from using cover combs for shearing instead of blades; and net benefits from changes in shearing policies (Figure 4.2). The latter accounts for farmers who were previously reluctant to change to winter-early spring shearing policies now being prepared to change policies because of the protection afforded by the cover comb. Most benefits were due to a reduction in sheep losses. This can be very variable, ranging from none (Everitt, 1961; Sumner and Scott, 1990; Dabiri *et al.*, 1994) to 75% (Hutchinson and McRae, 1969). Trial results suggest the losses in cover comb-shorn sheep are likely to be similar to those in unshorn sheep. For example, Dabiri *et al.* (1995a) found losses of 3% in unshorn and cover comb-shorn sheep, compared to 14% in conventional comb-shorn sheep in storms post-shearing. An Australian survey by Hutchinson (1968) indicated losses of 0.68% post-shearing over three years. Long term estimates of reductions in sheep losses due to cover comb shearing were therefore difficult to make. Losses are also variable between years. A sensitivity analysis based on a 0.5% and a 1% reduction in losses due to cover comb shearing was conducted on this variable because of its large impact on benefits accrued to the cover comb. Overall long term losses probably fall within this range.

Policy changes were likely to be from conventional full wool shearing to pre-lamb or eight month shearing policies, or from second shearing to eight month shearing. Net benefits in the first year from changing policies are likely to be positive for full wool to eight month shearing, and negative for the other alternatives. Once the new policy becomes established the benefits from all three policy changes are likely to be positive, although the size of the benefits will be dependent on the flock's wool production, wool prices, the differential between prices for different length or quality wools, the price effects arising from the timing of wool sales, and shearing costs. There could also be cash flow advantages associated with a change in policy (Parker and Gray, 1989), although this has not been taken into consideration in the present study.

Data on the extent of shearing policy changes, and numbers changing to the different policies in New Zealand are not published, but they are known to vary between years due to factors such as wool prices, cost of shearing and the introduction of new technology. Differences in income due to a change in shearing policy were calculated using a partial budget approach. These differences were sensitive to wool prices, yield differences and shearing costs, and are likely to vary between years. Differences calculated once a change in policy was established were \$2.06, \$1.01 and \$0.45 for a change from full wool to pre-lamb, second-shear to eight month and full wool to eight month shearing policies, respectively. Numbers changing to the different policies were unknown, therefore the average benefits from all shearing policy changes were assumed to be zero in the first year and $1.00/ewe for subsequent years.

A lower level of pasture intake (i.e. "feed savings") has also been identified as a possible advantage of cover comb shearing over conventional comb shearing, although results have been conflicting (Dabiri *et al.*, 1995a; Husain, 1996). The opportunity cost of feed savings was ignored in this study as it was impossible to identify accurately what this should be. Also, any feed savings are also likely to be countered by the intakes of the sheep that survived due to the reduction in losses.

Spreadsheet templates were developed to calculate the cover comb benefits. Copies of these can be found in Appendix VIII. Losses, production parameters, and costs and prices can be changed for sensitivity analysis. The benefits were particularly sensitive to the percentage reduction in losses. All costs are in 1996 prices (Lincoln University, 1996). Prices received have been based on an average of five years data (NZMWBES, 1991-1995; NZWB, 1991-1993; Wools of NZ, 1994-1996). Lambing percent is a function the number of cover comb-shorn ewes likely to be in lamb at shearing and the expected number of lambs born per ewe; this was estimated at 100%. Lamb losses were based on New Zealand Meat and Wool Board Economic Service (NZMWBES) farm survey data. Wool per lamb was estimated at 0.7 kg/lamb, allowing for the fact that not all lambs are shorn. Provision has also been made for the inclusion of feed savings, although, as outlined above, this has not been used in this case study. The benefits per sheep for a 0.5% and 1% reduction in losses due to cover comb shearing are shown in Table 4.2. The greater benefit due to a 1% reduction in losses is referred to as the higher benefit level (HBL), and the benefit from the 0.5% reduction in losses is referred to as the lower benefit level (LBL). Lamb losses were assumed to remain at 0.5% as lambs are not shorn in the winter or early spring months.

**Table 4.2 : Benefits ($/sheep) for two scenarios of reductions in sheep losses due to cover comb- rather than conventional comb-shearing.**

| Stock Class | High Benefit Level | | Low Benefit Level | |
|---|---|---|---|---|
| | % Losses | Benefit | % Losses | Benefit |
| **Ewes** | 1.0 | .5159 | 0.5 | .2579 |
| **Ewe Hoggets** | 1.0 | .3595 | 0.5 | .1798 |
| **Lambs** | 0.5 | .1555 | 0.5 | .1555 |

The proportion of cover comb-shorn ewes previously shorn with blades or now cover comb-shorn as a result of a policy change was calculated. The net benefit per ewe as a result of a reduction in losses, a change from blade shearing, and a policy change for the first and subsequent years was then weighted by the proportion of ewes affected by each change, to calculate the overall net benefit per ewe. The benefit from a change to cover comb-shearing from blade shearing was based on an extra $0.73 per sheep for blade shearing compared to conventional comb shearing (Lincoln University, 1996); the extra cost of cover comb- rather than conventional comb-shearing was allowed for later, in calculating the returns. Lamb, hogget and other sheep benefits were based on savings in animal losses only. The price received for sales of "other" sheep tends to be higher than that for hoggets. However, a smaller proportion of "other" sheep than hoggets are likely to be sold; some classes of "other" sheep are more likely to be killed on-farm. As this is only a small proportion of the total numbers the hogget value has been used for other sheep. Table 4.3 shows the benefits per ewe for cover comb shearing. High benefit level (HBL) and low benefit level (LBL) refer to the options used for the calculation of benefits from a reduction in losses.

**Table 4.3 : The proportional allocation of benefits ($/ewe) accruing to cover comb (CC) shearing from a reduction in losses, a change from blade to CC technology or a change in shearing policy.**

| | Percentage Of CC shorn sheep in category | | | Benefit ($/ewe) |
|---|---|---|---|---|
| **Year** | **Loss Redn** | **Blade to CC** | **Policy Change** | |
| **HBL (1.0% losses)** | | | | |
| **1990** | 97.0 | 3.0 | 0 | .522 |
| **1991 and 1992** | 94.5 | 3.0 | 2.5 | .534 |
| **1993+** | 92.0 | 3.0 | 5.0 | .547 |
| **LBL (0.5% losses)** | | | | |
| **1990** | 97.0 | 3.0 | 0 | .272 |
| **1991 and 1992** | 94.5 | 3.0 | 2.5 | .291 |
| **1993+** | 92.0 | 3.0 | 5.0 | .309 |

**Calculation of Investment Returns**

A spreadsheet was used for the calculation of the return on investment in development, research and extension of cover comb shearing because these are relatively easy to programme and modify. Hard copies and a description of the spreadsheet templates developed for the study are included in Appendix VIII. Numbers shorn with a cover comb, both with and without the research, were calculated for years in which it was believed the rate of technology uptake was changing. For this study, the years calculated were 1989, 1992, 1995 and 2000. Values for the remaining years were extrapolated from these points. Numbers were assumed to have reached a ceiling level by 2000, and the 2000 figures were used for years 2001 to 2020. The return to investment was calculated as an internal rate of return (IRR), and a net present value (NPV) and a benefit-cost ratio (BCR) for a specified discount rate.

The numbers shorn for each year were based on opening sheep numbers for the national flock. The proportions of sheep shorn, and within the different sheep classes, were used to calculate the numbers of sheep shorn by stock class. These proportions used were based on NZMWBES data. Calculation of these parameters is described in a later section (see pages 100 - 106).

*Calculation of Technology Uptake for a Given Year*

Numbers shorn with, and without, a cover comb can be calculated on a national, North and South Island, or regional basis, depending on whether the research being evaluated is likely to affect all or only some regions. If the technology uptake is unevenly distributed throughout New Zealand it may be more appropriate to do the calculations by Island or region, as numbers in the different stock classes, and the popularity of various shearing policies, vary between regions as illustrated in Table 4.4. Total numbers of sheep shorn are then calculated on a national basis.

Information on the number of sheep shorn in New Zealand is not readily available. However, information on opening numbers, or estimated opening numbers of sheep (for the year beginning 1 July) is available. When the opening number of sheep is entered, estimates of the numbers shorn in each stock class, including the number of ewes shorn once and twice yearly, and the number of shearings is automatically calculated. The proportions of sheep shorn or sheep per class can be changed if required.

Opening numbers, up to 1996 were provided by the NZMWBES. These can also be found in NZMWBES and Wools of New Zealand publications. Nationally, sheep numbers in the next decade are anticipated to remain the same or decline slightly (Williams, R., 1997, personal communication). The NZMWBES predicts that there will be fewer sheep and beef cattle farms in future, but that farms will increase in size, with more sheep per farm. Dairying, forestry and urban sprawl, particularly lifestyle blocks, will take over more land, although the first two will occur at a reduced rate to that at present (Williams, R., 1996, personal communication).

Equations 1 to 7 provide a mathematical description of the calculation of the numbers shorn with, and without, a cover comb for the various stock classes. These equations are year- and area- (national, Island or region) specific. Numbers are in thousands. Initially, the number of adult sheep by class (two-tooth ewes, mixed-age ewes, ewe hoggets, wether hoggets, wethers and rams) on-hand at 1 July was calculated as described in Equation 1.

$N_C = ON \times PN_C$ (Equation 1)

where:

$N_C$ = number of sheep in class c;

ON = opening number of sheep;

$PN_C$ = proportion of opening number of sheep in class c;

c = 1 = two-tooth ewes;

c = 2 = mixed-age ewes;

c = 3 = ewe hoggets;

c = 4 = wether hoggets;

c= 5 = wethers;

c = 6 = rams.

The numbers of sheep shorn in each class were estimated next as:

$NS_C = N_C \times PS_C$ (Equation 2)

where:

$NS_C$ = number of sheep shorn in class c;

$PS_C$ = proportion of sheep shorn for class c.

The calculation of the proportions shorn in each class is described in a later section.

Some classes were amalgamated, therefore sheep shorn were recoded into groups before the calculation of sheep shorn with, and without, the research. These groups were defined as:

$S_k$ = number of sheep shorn in group k;

k = 1 = two-tooth and mixed-age ewes;

k = 2 = ewe hoggets;

k = 3 = wether hoggets, wethers and rams;

k = 4 = lambs.

Adult sheep were recoded into three groups as defined by Equations 3 to 5.

$$S_1 = \sum_{C=1}^{2} NS_C \qquad \text{(Equation 3)}$$

$$S_2 = NS_3 \qquad \text{(Equation 4)}$$

$$S_3 = \sum_{C=4}^{6} NS_C \qquad \text{(Equation 5)}$$

Lambs shorn were based on opening numbers. This is a function of the proportion of ewes to opening numbers, ewes mated to those present at 1 July, lambing percentage and the proportion of lambs shorn. For simplicity, the number of lambs shorn was calculated directly from opening numbers for this study, as the effects of lamb shearing on cover comb benefits are minimal (see Chapter 3). The calculation for lambs shorn was:

$$S_4 = ON \times PLS \qquad \text{(Equation 6)}$$

where:

PLS = proportion of lambs shorn.

The next section calculates the numbers shorn with and without the research. Proportions of ewes, ewe hoggets, lambs and other sheep shorn with a cover comb, both with, and without, the research were entered.

The calculation for the numbers in each group shorn with a cover comb, both with, and without, the research was calculated as:

$$NC_{kr} = PC_{kr} \times S_k \qquad \text{(Equation 7)}$$

where:

$NC_{kr}$ = number of sheep cover comb-shorn in group k for research option r;

$PC_{kr}$ = proportion of sheep cover comb-shorn in group k for research option r;

r = 1 = with the research;

r = 2 = without the research.

Finally, total numbers shorn with a cover comb, both with and without research, were calculated nationally, where these calculations have been done either by Island or region. This can also be used as a cross check to ensure numbers calculated nationally, by Island or by region add up to a similar figure on a national basis.

*Calculation of Investment Returns*

The return to investment was now calculated as an internal rate of return, and a net present value and a benefit-cost ratio at the specified discount rate.

Costs and benefits are valued at a particular point in time. For the cover comb study these were valued at 1996 prices (i.e. the base year).

For the cover comb study, years 1989 to 2020 have been used, to allow for up to 30 years after the beginning of the research. The period 1972 to 2020 has been used where the development costs for the cover comb are included. After 20 years benefits are likely to be small due to discounting (Gittinger, 1982). However, some past evaluations of returns to investment in agricultural research have used longer periods e.g. 40 years was used in a cost-benefit analysis of some CSIRO research projects (Ralph, 1993). If benefits still look to be significant after 30 years the period can be extended, or the benefit in the final year can be capitalised to infinity. Another alternative used in cost-benefit analysis is to allow a residual value for these benefits in the final year, however this is not a practical option for this study.

Year number is the number assigned to a year. This number is also used in the calculation of present value.

$$y = \text{year} - \text{base year} \qquad \text{(Equation 8)}$$

where:

y = year number;

year = year the calculations are being completed for;

base year = 1996.

Opening numbers for each year were included to provide background information on the initial figure that the number of sheep shorn with a cover comb was based on, and shows the expected trend in sheep numbers. The proportion of the total sheep shorn with a cover comb, both with and without the research, and the difference were also calculated. Opening numbers are in thousands.

Benefits from research can only be attributed to gains that would have occurred with the research. Sheep would still be cover comb-shorn without the research, although in lesser numbers. Factors other than the research can also impact on the farming system and affect technology uptake; this must also be considered in predicting technology uptake. To allow for these factors, the increases in cover comb uptake due to the research were conservative. The difference in sheep shorn with, and without, the research for each class was used to calculate benefits from the research as shown in Equation 9. This difference in numbers was calculated for each group as:

$$NCD_{ky} = NC_{k1y} - NC_{k2y} \qquad \text{(Equation 9)}$$

where:

$NCD_{ky}$ = difference between numbers of sheep shorn with, and without, a cover comb for group k in year y;

$NC_{k1y}$ = number of sheep cover comb-shorn with research (r=1) for group k in year y;

$NC_{k2y}$ = number of sheep cover comb-shorn without research (r=2) for group k in year y.

Production costs were then calculated. These were calculated as:

$$C_{ky} = NCD_{ky} \times CS_{ky} \times 1000 \qquad \text{(Equation 10)}$$

where:

$C_{ky}$ = total production costs for group k in year y;

$CS_{ky}$ = production costs per sheep for group k in year y.

A multiplier of 1000 was included as sheep numbers up till now have been expressed in thousands, rather than millions. A cost of $0.08 per sheep was used in the cover comb study, as this was the extra cost of shearing with a cover comb compared to a conventional comb. This extra cost was based on the rate allowed for by the Shearing Contractors Association (Kidd, R., 1997, personal communication).

Benefits were calculated in a similar manner to costs as:

$$B_{ky} = NCD_{ky} \times BS_{ky} \times 1000 \qquad \text{(Equation 11)}$$

where:

$B_{ky}$ = total benefits for group k in year y;

$BS_{ky}$ = production benefits per sheep for group k in year y.

Total costs were calculated next as:

$$TC_y = D_y + R_y + E_y + \sum_{k=1}^{4} C_{ky} \qquad \text{(Equation 12)}$$

where:

$TC_y$ = total costs in year y;

$D_y$ = development costs in year y;

$R_y$ = research costs in year y;

$E_y$ = extension costs in year y.

If only the return to research and extension is being considered, development costs should be set to zero. If development is included, sheep shorn without research should be set at zero, as without development there would be no cover comb.
Total benefits were calculated in a similar manner to total costs. The equation is:

$$TB_y = \sum_{k=1}^{4} B_{ky} \qquad \text{(Equation 13)}$$

where:

$TB_y$ = total benefits in year y.

The net benefit was then calculated.

$$NB_y = TB_y - TC_y \qquad \text{(Equation 14)}$$

where:

$NB_y$ = net benefits in year y.

The present value for each year, at the specified discount rate, was calculated, as shown in Equation 15.

$$PV_y = \frac{NB_y}{(1 + i)^y} \qquad \text{(Equation 15)}$$

where:

$PV_y$ = present value in year y;

i = discount rate.

The present values of the benefits and costs in each year, at the specified discount rate (i) were then calculated. These were used in the calculation of the benefit-cost ratio. Costs were for the research, development and extension; the benefits were net benefits of cover comb shearing (benefits less extra shearing costs). The equations are:

$$PVB_y = \frac{\sum_{k=1}^{4} B_{ky} - \sum_{k=1}^{4} C_{ky}}{(1+i)^y} \qquad \text{(Equation 16)}$$

$$PVC_y = \frac{D_y + R_y + E_y}{(1+i)^y} \qquad \text{(Equation 17)}$$

where:

$PVB_y$ = present value of the benefits in year y;

$PVC_y$ = present value of the costs in year y;

For the cover comb study discount rates of 5% and 10% were used. The discount rate is a real discount rate as the effect of inflation has been allowed for by using constant 1996 prices for all years. This rate is likely to be closer to 5% than 10%. Over the past six years the difference in between inflation and interest rates (90 day bills and 5 year government stock) has ranged from 4.0% to 6.7% (Statistics NZ, 1991 - 1996).

The net present value (NPV), internal rate of return (IRR) and benefit-cost ratio (BCR) have been calculated for the years up to, and including 2000, 2005, 2010 and 2020. Examples calculating the NPV and BCR until 2020 are described in Equations 18 and 19. Year -7 equals 1989 and year 24 equals 2020, relative to the 1996 base year.

$$NPV_{2020} = \sum_{y=-7}^{24} PV_y \qquad \text{(Equation 18)}$$

$$BCR_{2020} = \frac{\sum_{y=-7}^{24} PVB_y}{\sum_{y=-7}^{24} PVC_y} \qquad \text{(Equation 19)}$$

The internal rate of return is the discount rate at which the net present value is 0; this is calculated by a spreadsheet function. The cells containing the present values (i.e. Equation 14) for the years concerned were specified in this function.

## Sensitivity Analysis

A worksheet was adapted to allow for sensitivity analysis, because the actual values for a number of critical inputs to the model were not defined. Opening numbers of sheep were entered and the number of sheep shorn in each group was calculated, based on sheep shorn in each group as a proportion of opening numbers. The percentage of sheep shorn using the technology, both with and without the research, was entered for each group, and the numbers shorn were calculated as the number of sheep shorn in that group multiplied by this percentage. The remaining calculations are as described in the previous section.

The percentages shorn with and without the technology, the benefits and costs associated with the research, development and extension, and the discount rate were adjusted to compare the sensitivity of the returns to these changes.

## Calculation of Spreadsheet Parameters

*Calculation of the Proportions of Sheep Shorn and in each Stock Class*

The proportions of sheep shorn, both once and twice, and the numbers in each stock class, were calculated from NZMWBES farm class data. The NZMWBES farm classes are South Island (S.I.) high country, S.I. hill country, S.I. finishing and breeding, S.I. intensive finishing, S.I. mixed finishing, North Island (N.I.) hard hill country, N.I. hill country and N.I. intensive finishing farms. The farms selected exclude government-owned farms and farms with fewer than 750 stock units. The NZMWBES monitors between 540 and 550 farms nationally, from five regions (NZMWBES, 1996). These regions are Auckland/Bay of Plenty, Hawkes Bay/Poverty Bay/Wairarapa, Taranaki/Wanganui/Wellington, Canterbury/Marlborough/West Coast and Otago/Southland. Sufficient farms are sampled from the different classes within the regions to ensure a fair representation is made. The balance of farm classes sampled both within a region and nationally is not necessarily representative, so these data have to be weighted to produce meaningful data on a national or regional basis.

Numbers at opening (as at 1 July) with respect to the: total number of sheep, number of adult sheep shorn and second shorn, lambs shorn, and numbers of ewes, ewe hoggets, wether hoggets, wethers and rams for each farm class were entered into a spreadsheet. These were then weighted by the number of farms in that class to reflect the region, the North or South Island, or the national flock. Total numbers for each category were then calculated (as the total number of sheep across all farm classes, with the number of sheep in a farm class calculated as the number of farms multiplied by the numbers of sheep per farm). These figures were used to calculate the numbers in each stock class, or the numbers shorn, as a proportion of total numbers. A sample of a worksheet for 1994/95 national figures can found in Appendix VIII. Data from 1990/91 to 1994/95 were used, with the average over the five years calculated. These are summarised in Table 4.4. Data weighted by the NZMWBES for 1990/91 to 1994/95 were used to verify these figures where available. Regions are Auckland/Waikato/Bay of Plenty (Auck), Hawkes Bay/Poverty Bay/Wairarapa (EC), Taranaki/Wanganui/Wellington (T/W), Canterbury/Marlborough/West Coast (C/M) and Otago/Southland (O/S).

**Table 4.4 : Sheep shorn and in the different stock classes as a proportion of opening numbers (as at 1 July) based on 1990/91 to 1994/95 averages.**

| | NZ | NI | SI | Auck | EC | T/W | C/M | O/S |
|---|---|---|---|---|---|---|---|---|
| **Stock Class** | | | | | | | | |
| **2T Ewes** | .1686 | .1777 | .1612 | .1787 | .1769 | .1771 | .1527 | .1696 |
| **MA Ewes** | .5392 | .5122 | .5616 | .5114 | .5126 | .5129 | .5630 | .5601 |
| **Ewe Hgts** | .2006 | .2207 | .1840 | .2215 | .2203 | .2197 | .1789 | .1890 |
| **Wether Hgts** | .0546 | .0709 | .0411 | .0692 | .0722 | .0721 | .0522 | .0302 |
| **Wethers** | .0265 | .0074 | .0422 | .0080 | .0069 | .0071 | .0430 | .0414 |
| **Rams** | .0104 | .0111 | .0099 | .0111 | .0110 | .0110 | .0102 | .0096 |
| **Shearings** | | | | | | | | |
| **Sheep shorn** | .9033 | .8756 | .9262 | .8757 | .8758 | .8750 | .9201 | .9321 |
| **Shorn twice** | .2966 | .5061 | .1244 | .5074 | .5060 | .5038 | .0843 | .1638 |
| **Lambs shorn** | .4353 | .5766 | .3191 | .5854 | .5679 | .5742 | .2830 | .3545 |

*Calculation of the Proportion of Sheep Shorn per Class*

To calculate sheep shorn per class, it was necessary to estimate the proportions shorn by class, as this data was unavailable. It was assumed for the purpose of this study that wether hoggets were unshorn (with most presumably sold prior to shearing) and that the proportion of adult sheep shorn was the same across all other classes i.e. ewes, hoggets, wethers and rams. This means that not all sheep within a class are shorn each year (i.e. some may be culled or die before lambing, some may be "stragglers" and some may be shorn at an interval greater than 12 months).

This proportion was calculated as:

$$PSC = \frac{PS}{1 - PN_4} \qquad \text{(Equation 20)}$$

where:

PSC = proportion of adult sheep shorn for classes c = 1,2,3,5 and 6;

PS = proportion of adult sheep shorn based on opening numbers;

$PN_4$ = proportion of wether hoggets shorn based on opening numbers.

Note: $PS_C$ (Equation 2) = PSC for classes 1, 2, 3, 5 and 6, and 0 for class 4 in this study.

A check on the calculated proportions shorn was included. To complete the check, the North and South Island figures were converted into national figures. The same check was applied to the regional figures which are expressed as North and South Island, and national values, respectively (i.e. proportion weighted by the number of sheep in the region). The proportions for the different classes can be changed and this check ensures that the figures calculated nationally and by Island remain similar.

A shearing check was also included to check that the total number shorn by class was similar to that calculated using opening numbers. (Note: Rounding errors with large numbers means that the regional values scaled to an Island or national equivalent are unlikely to be the same as the original national value). The equation for the shearing check was:

$$NS\ (check) = \sum_{C=1}^{6} (N_C \times PSc) \qquad \text{(Equation 21)}$$

where:

NS = number of adult sheep shorn;

$NS_C$ = number of sheep shorn in class c;

$PS_C$ = proportion of sheep shorn for class c.

*Calculation of Numbers of Ewes Shorn and Ewe Shearings based on Opening Numbers*

The number of sheep shorn and sheep shorn twice was calculated as:

$$NS = ON \times PS \qquad \text{(Equation 22)}$$

$$NS2 = ON \times PS2 \qquad \text{(Equation 23)}$$

where:

NS = number of adult sheep shorn;

NS2 = number of adult sheep shorn twice;

PS = proportion of adult sheep shorn;

PS2 = proportion of adult sheep shorn twice.

For this study it has been assumed that second shearing is applied only to ewes; hoggets, wethers and rams are assumed to be shorn only once annually. Sheep are only shorn once as hoggets, however some are likely to be shorn again (about March) as two-tooths. This would affect the number of ewes (on hand at 1 July) shorn twice, as these two-tooth shearings are included in the number of second shearings. This in turn impacts on the number of ewes shorn twice. The proportion of hoggets shorn again as two-tooths was unavailable, and estimates of these figures varied between industry sources. For this study it was assumed that the majority of ewe hoggets in the North Island are shorn again as two-tooths, and a figure of 70% was used, allowing for losses and culling between shearings. Corresponding estimates of 20% and 50% were used for the upper and lower South Island, respectively. This came to a national figure of 54%. The number of ewes shorn once and twice, and the number of ewe shearings was calculated as:

$$ES2 = NS2 - (S_2 \times P2T) \qquad \text{(Equation 24)}$$

$$ES1 = S_1 - ES2 \qquad \text{(Equation 25)}$$

$$ESH = (NS + NS2) - (\sum_{k=2}^{3} S_k + (S_2 \text{ x } P2T)) \quad \text{(Equation 26)}$$

where:

ES2 = number of ewes shorn twice;

ES1 = number of ewes shorn once;

ESH = number of ewe shearings;

P2T = proportion of ewe hoggets shorn as two-tooths.

$S_k$ = number of sheep shorn in group k;

k = 1 = two-tooth and mixed-age ewes;

k = 2 = ewe hoggets;

k = 3 = wether hoggets, wethers and rams;

The next section, total numbers shorn, was a cross check to ensure numbers calculated nationally, by Island or by region, add up to a similar figure on a national basis. The error is very small, usually less than 1% difference in a variable calculated the three different ways.

*Calculation of Proportion of Ewes Shorn based on Ewe Shearings*

The proportion of ewes shorn with a cover comb can be calculated where the proportion of cover comb shearings is known, rather than the proportion of cover comb-shorn ewes e.g. contractors data. This can be done both "with" and "without" the research, if required. The calculation for the proportion of ewes shorn is given in Equation 27.

$$PC_{1r} = \frac{PSH_{1r} (ESH + (S_2 \text{ x } P2T))}{S_1} \quad \text{(Equation 27)}$$

where:

$PC_{kr}$ = proportion of sheep cover comb-shorn in group k for research option r;

r = 1 = with the research;

r = 2 = without the research.

$PSH_{1r}$ = proportion of ewe cover comb-shearings with the research option r;

For this study it was assumed that second shorn ewes are shorn only once with a cover comb, and two-tooths (shorn already as a hogget) are not shorn with a cover comb as two-tooths. This increases the proportion of cover comb-shearing of ewes (as at 1 July). Other classes were assumed to be shorn only once, so shearings and numbers shorn will be the same.

## SCENARIO ANALYSIS AND DISCUSSION

### Returns to Research and Extension

Two adoption uptakes (Table 4.1), two benefit levels based on a 0.5% and a 1.0% reduction in losses due to cover comb shearing (Tables 4.2 and 4.3), and discount rates (DR) of 5% and 10% were used. The returns from the HBL and the LBL for the periods 1989 to 2000, 2005, 2010 and 2020, are presented in Tables 4.5 and 4.6.

**Table 4.5 : The returns to research and extension for cover comb technology at the high benefit level.**

| | Adoption Rate 1 | | Adoption Rate 2 | |
|---|---|---|---|---|
| **Return[1]** | **DR = 5%** | **DR = 10%** | **DR = 5%** | **DR = 10%** |
| **IRR (%)** | 1330.5 | 1330.5 | 1099.8 | 1099.8 |
| | | | | |
| **NPV to 2000** | 21.98 | 22.55 | 15.61 | 16.11 |
| **NPV to 2005** | 31.45 | 29.43 | 22.32 | 20.99 |
| **NPV to 2010** | 38.86 | 33.70 | 27.57 | 24.02 |
| **NPV to 2020** | 49.22 | 38.00 | 34.92 | 27.06 |
| | | | | |
| **BCR to 2000** | 52.22 | 45.52 | 37.37 | 32.81 |
| **BCR to 2005** | 74.27 | 59.10 | 53.00 | 42.44 |
| **BCR to 2010** | 91.54 | 67.53 | 65.25 | 48.41 |
| **BCR to 2020** | 115.69 | 76.02 | 82.36 | 54.43 |

[1] Returns are presented as an internal rate of return (IRR) (%), a net present value (NPV) ($millions) and a benefit-cost ratio (BCR).

**Table 4.6 : The returns to research and extension for cover comb technology at the low benefit level.**

| | Adoption Rate 1 | | Adoption Rate 2 | |
|---|---|---|---|---|
| **Return**[1] | **DR = 5%** | **DR = 10%** | **DR = 5%** | **DR = 10%** |
| **IRR (%)** | 584.2 | 584.2 | 484.6 | 484.6 |
| | | | | |
| **NPV to 2000** | 10.14 | 10.34 | 7.03 | 7.22 |
| **NPV to 2005** | 14.63 | 13.61 | 10.14 | 9.48 |
| **NPV to 2010** | 18.15 | 15.64 | 12.58 | 10.88 |
| **NPV to 2020** | 23.07 | 17.68 | 15.99 | 12.30 |
| | | | | |
| **BCR to 2000** | 24.61 | 21.42 | 17.37 | 15.24 |
| **BCR to 2005** | 35.09 | 27.87 | 24.63 | 19.71 |
| **BCR to 2010** | 43.29 | 31.88 | 30.32 | 22.49 |
| **BCR to 2020** | 54.76 | 35.91 | 38.26 | 25.28 |

[1] Returns are presented as an internal rate of return (IRR) (%), a net present value (NPV) ($millions) and a benefit-cost ratio (BCR).

The internal rates of return at the HBL were 1330.5% and 1099.8% for the AR1 and AR2 scenarios, respectively. At the LBL these were 584.2% and 484.6% for the AR1 and AR2 scenarios, respectively. The very high internal rates of return were largely a reflection of the timing of the costs and benefits; in this study the high rates were achieved by high net benefits in the years immediately following the year that net costs occur. This meant that net benefits at these IRRs were achieved from years close to the year costs were incurred; net benefits from other years were negligible once discounting had occurred. As a result the IRR for all time periods was the same (i.e. had been discounted to a negligible level by 2000).

The net present values to 2020 ranged from $27.06 million to $49.22 million at the HBL, and $12.30 million to $23.07 million at the LBL. These were greater at AR1 than AR2, and at a discount rate of 5% than 10%. NPV to 2000 ranged from $15.61 million to $22.55 million at the HBL, and $7.03 million to $10.34 million at the LBL. It appears from this that this research has been profitable, considering that the decision rule for NPV is that any project with a NPV greater than or equal to zero should be approved. Even at the lowest rates these returns were very high.

As for the net present value, the benefit-cost ratios were also very high. The research and extension costs came to present values of $429,200 and $506,560 at the 5% and 10% discount rates, respectively. These costs were low in comparison to the benefits achieved.

The returns to research and extension in this study were particularly sensitive to the reduction in sheep losses. For example, a 0.5% reduction in sheep losses, with all other variables held constant, generated a 128% difference in the IRR, a 113% to 122% difference in the NPV and a similar difference in the BCR. The overall national reduction in sheep losses due to the use of the cover comb is likely to be low and, for reasons outlined earlier in this Chapter, is not able to be estimated with a high degree of accuracy. Furthermore, post-shearing losses can be variable between regions, years or farms. Consequently, an overall net reduction in losses of 0.5% and 1% was assumed for all years in the cost-benefit analysis. The true value of the reduction in losses due to cover comb-shearing possibly falls between these two levels, and accordingly the returns to research and extension can be estimated by interpolation using the results in Tables 4.5 and 4.6.

The effect of a change in the discount rate was not great. The NPVs were higher for the 10% discount rate for the period to 2000, and lower for the remaining periods; the BCR were all higher for the lower discount rate. The rapid adoption of the technology in a short space of time accounted for the higher NPV at the 10% discount rate for the 1989 to 2000 period. Only one year (1989) had a negative present value, and at the HBL the research and extension paid for itself in one year. Rapid technology uptake was one reason for the high returns found in this study. A delay of three years in the uptake of the technology would have reduced the IRR from 1330% to 108% (HBL, AR1) under the same scenario. The NPV and BCR at the 5% discount rate for the 1989 to 2020 period would be reduced from $52.22m and 116:1 to $39.54m and 93:1, respectively. While this still represents a very high return, it also emphasises the importance of effective development and technology transfer to minimise time lag effects on research benefits.

The large sheep population that the research applied to was a major factor in explaining the high returns. For example, a 1% increase in the number of ewes in New Zealand shorn with a cover comb will give a $142,840 benefit per year (assuming 48 million sheep x .7079 x .9554 x 0.01 = 324,637 ewes cover comb-shorn, at a benefit of $0.52 - $0.08 = $0.44/ewe). A sensitivity analysis was conducted (Table 4.7) comparing the results of different technology uptakes for ewes, with benefits from a reduction in losses only i.e. $0.258 and $0.516 per ewe. If adoption uptake starts in 1990 and increases at a rate of 2% per year until the ceiling adoption rate is reached, benefits would be as shown in Table 4.7. Note results are for the 1989 to 2020 period.

**Table 4.7 : The returns to research and extension on cover comb shearing of ewes at four adoption rates.**

| | High Benefit Level | | Low Benefit Level | |
|---|---|---|---|---|
| **Return[1]** | **DR = 5%** | **DR = 10%** | **DR = 5%** | **DR = 10%** |
| **1% Adoption Rate** | | | | |
| **IRR (%)** | 468 | 468 | 90 | 90 |
| **NPV ($m)** | 2.77 | 2.23 | 0.88 | 0.61 |
| **BCR** | 7.46 | 5.40 | 3.04 | 2.20 |
| **2% Adoption Rate** | | | | |
| **IRR (%)** | 1072 | 1072 | 356 | 356 |
| **NPV ($m)** | 5.97 | 4.97 | 2.18 | 1.73 |
| **BCR** | 14.92 | 10.80 | 6.09 | 4.41 |
| **5% Adoption Rate** | | | | |
| **IRR (%)** | 1167 | 1167 | 450 | 450 |
| **NPV ($m)** | 14.69 | 12.00 | 5.74 | 4.60 |
| **BCR** | 35.22 | 24.70 | 14.37 | 10.08 |
| **10% Adoption Rate** | | | | |
| **IRR (%)** | 1171 | 1171 | 458 | 458 |
| **NPV ($m)** | 27.42 | 21.56 | 10.94 | 8.50 |
| **BCR** | 64.89 | 43.57 | 26.48 | 17.78 |

[1] Returns are presented as an internal rate of return (IRR) (%), a net present value (NPV) ($millions) and a benefit-cost ratio (BCR).

Thus, a small increase in the uptake would produce high returns. It can also be seen that the relationship between the adoption rate and the discounted measures of return, particularly IRR, are non-linear with the timing of the benefits as well as the size of benefits having an effect; that is, the earlier the benefits the greater the return.

The effect of an increase in research costs was also assessed. This showed that at a discount rate of 5%, AR1 and HBL the research costs could have been seventy times greater, and at the LBL thirty times greater, and the research would still have been worthwhile. At the HBL, with research costs seventy times greater, the IRR, NPV and BCR for the period 1989 to 2020 were 13.8%, $24.30 million and 1.96:1, respectively. At the LBL, with research costs thirty times greater IRR, NPV and BCR were 15.5%, $12.56 million and 2.16:1, respectively. However, in both these cases, the returns for the period 1989 to 2000 were not worthwhile i.e. the IRR was less than 5%. This illustrates the importance of the time period over which the new technology is assumed to provide benefits on the returns to investment in research and extension. It also demonstrates that the high returns from one research success could cover the costs of a lot of other research.

The returns to research and extension were capitalised to infinity, at AR1, for both a 10% and a 5% discount rate, and a HBL and a LBL. The NPV and the BCR increased approximately 32% at the 5% discount rate, and approximately 6.4% at the 10% discount rate. At the HBL the net present values were $49.43 million and $64.88 million for the 10% and 5% discount rates, respectively. This shows that returns are likely to be greater, particularly at the 5% discount rate, if the technology does not become redundant. For the purpose of the study it was considered unlikely that the technology would be superseded in the short term. However, this is unknown for the long term, and therefore it was considered inappropriate to capitalise returns to infinity.

**Returns to Development, Research and Extension**

The return to investment in research, development and extension of cover comb technology was calculated (Table 4.8). For simplicity, the benefits were assumed to be from a reduction in losses only i.e. $0.258 and $0.516 for a 0.5% and a 1.0% reduction in losses, respectively. Benefits were attributed to all sheep cover comb shorn; that is, the "without" scenario is no sheep cover comb shorn, because with no development there would have been no cover comb. The periods tested were 1972 to 1988, 2000, 2005, 2010 and 2020. Results are shown for a discount rate of 5%.

The adoption rate used from 1989 onwards was that for AR1. Prior to 1989, uptake was assumed to have been low till the early 1980's (2.9% of sheep shorn in 1981). The main uptake was assumed to have occurred in the South Island in the early 1980's after the cover comb was trialled at Nokomai Station, with 9.9% of sheep cover comb shorn in 1988.

The extra $0.08 per sheep for cover comb shearing was both included and excluded from the analysis as it can be argued that while this is an extra cost to farmers, it is to compensate shearers for the extra cost of supplying cover combs and the relatively new cutters required to use these. This in turn represents a benefit to Sunbeam Corporation Ltd who developed the cover comb. Therefore this is not a cost where development is included. There will be some error in this assumption as Sunbeam Corporation Ltd was not the only manufacturer of cutters, nor were they the only manufacturer of cover combs from 1994.

**Table 4.8 : The returns to research, development and extension of cover comb shearing at a 5% discount rate, at both the high and a low benefit levels and including and excluding the extra $0.08 shearing cost.**

| | High Benefit Level | | Low Benefit Level | |
|---|---|---|---|---|
| **Return[1]** | **Cost** | **No Cost** | **Cost** | **No Cost** |
| **IRR to 1988** | 82.5 | 92.9 | 46.5 | 58.4 |
| **IRR to 2000** | 82.5 | 92.9 | 47.2 | 58.7 |
| **IRR to 2005** | 82.5 | 92.9 | 47.2 | 58.7 |
| **IRR to 2010** | 82.5 | 92.9 | 47.2 | 58.7 |
| **IRR to 2020** | 82.5 | 92.9 | 47.2 | 58.7 |
| | | | | |
| **NPV to 1988** | 33.64 | 40.04 | 13.13 | 19.53 |
| **NPV to 2000** | 91.76 | 109.42 | 36.26 | 53.92 |
| **NPV to 2005** | 111.25 | 132.72 | 44.15 | 65.63 |
| **NPV to 2010** | 126.52 | 150.98 | 50.34 | 74.80 |
| **NPV to 2020** | 147.86 | 176.49 | 58.98 | 87.61 |
| | | | | |
| **BCR to 1988** | 35.71 | 42.32 | 14.55 | 21.16 |
| **BCR to 2000** | 56.30 | 66.94 | 22.85 | 33.49 |
| **BCR to 2005** | 68.04 | 80.98 | 27.61 | 40.55 |
| **BCR to 2010** | 77.24 | 91.98 | 31.33 | 46.07 |
| **BCR to 2020** | 90.10 | 107.35 | 36.54 | 53.80 |

[1] Returns are presented as an internal rate of return (IRR) (%), a net present value (NPV) ($millions) and a benefit-cost ratio (BCR).

At a 5% discount rate the cost of the early development came to a present value of $969,122, the later development to $261,151, and the research and extension to $429,200. The adoption rate was low initially, but, due to the large numbers of sheep in New Zealand, only a small proportion of the national flock would need to be shorn with the technology for it to show a high return.

The result of no research and extension on the returns was also tested at the HBL. The extra cost of shearing was included. Adoption rate 1 with no research and extension was assumed for the years 1989 to 2020. The IRR remained at 82.5%. The NPV was $70.99m, $81.55m, $89.83m and $100.40m for periods ended 2000, 2005, 2010 and 2020, respectively. Similarly the BCR was 58.7:1, 67.3:1, 74.0:1 and 83.4:1 for periods ended 2000, 2005, 2010 and 2020, respectively. This shows that the 1989 to 1995 research and extension had an impact on research returns. For example, the NPV to year 2020 was $100.40 million without the research and extension and $147.86 with the research and extension.

**General Discussion**

There are other benefits associated with cover comb shearing which were not included in this analysis. The purpose of the cover comb was to afford sheep greater protection from inclement weather after shearing, so reducing losses and possibly feed intake. These were the only advantages considered in the cost-benefit analysis. Other advantages include a better spread of labour, a reduction in time spent moving sheep to shelter in adverse climatic conditions post-shearing, management flexibility, peace of mind, animal welfare and sales advantages. If a financial value had been attributed to these benefits, and they had been included in the analysis, the returns would have been greater.

This study has not taken equity issues into consideration. Sheep farmers throughout New Zealand contribute to Wools of New Zealand funding. Regionally, the Auckland and North Auckland area are likely to have received little or no return from this research and extension. The technology was already in use in the South Island, although there was some further uptake of the technology post-1989, and therefore a return to investment here. There will have been a return to investment in the East Coast and lower North Island regions where cover comb technology uptake was unlikely to have occurred to any extent without the research and extension.

There is likely to be no difference in returns to early and late adopters, other than that early adopters captured the benefits sooner. An increase in uptake is unlikely to alter the value of the wool output, unless large numbers use cover comb technology to change shearing policies to eight month or pre-lamb shearing, affecting the types of wool available and the timing of wool sales, and possibly their relative prices. There has been no attempt to attribute the returns separately to those providing the funding e.g. farmers, Wools of New Zealand, NZ Government, Massey University.

The cost-benefit model should prove useful in *ex ante* research evaluation. While a specific return is unlikely to be able to be calculated because of the uncertainty of some variables, sensitivity analysis could be used to identify whether the proposed research is likely to be worthwhile under different sets of conditions, and to identify the variables which are likely to have the greatest impact on returns to the investment in research and extension. In this respect the model output will aid in the decisions on how and where research funds should be allocated. The information gathering process for the cost-benefit analysis, by itself, will benefit decision-makers in allocating research funding.

Considering the difficulties of identifying the information required for the cost-benefit analysis, and the fact that a result cannot be predicted with any accuracy, it is hardly surprising that cost-benefit analysis has not been widely used in the past for research evaluation. Cost-benefit analysis should be used in association with other methods, such as scoring methods, in allocating research funds as there could be factors not allowed for in the cost-benefit analysis. In this study there were a number of intangibles not included in the cost-benefit analysis which should have been considered in decision making e.g. peace of mind. This study also found that there could be benefits associated with a research project not likely to be considered in an *ex ante* analysis e.g. sales advantages. This could also apply to costs.

This study demonstrated that even *ex post*, the returns to research cannot be predicted with any certainty, as the data required to predict the research and extension return may still be unknown. Monte-carlo simulation techniques could be used, both *ex post* and *ex ante*, to calculate a distribution of possible returns, by predicting a large number of returns based on the different combinations of input variables. The disadvantages are that: this involves even greater data requirements e.g. data distributions for the uncertain input variables; this could be complicated because the outcome of one variable may affect another variable e.g. the adoption level in one year is likely to be related to the previous year's adoption level; and the more complicated the technique, the more difficult it is to use and understand. Matrices could also be used to predict adoption uptakes, however this still requires some estimation of uptakes.

The IRR can be very sensitive where the capital costs (research and extension costs in this case) are low in relation to the size and variability of the net benefits, often leading to a high IRR (Ward *et al.*, 1991). This is applicable to most agricultural projects. The IRR is sensitive to the factors affecting the net benefits and these are often the factors that are uncertain in agricultural projects e.g. crop yields, output prices, and input units and prices. Therefore the internal rates of return should be treated with caution in decision-making.

The returns to research expenditure estimated in this study are very high in comparison to many of the returns cited in past studies. These earlier studies have primarily derived aggregate returns to research or returns to plant breeding research, and in general the IRR has been between 30 and 50%. Many of these have been calculated using a production function approach. A summary of some returns to research calculated using a cost-benefit analysis technique similar to that used for the cover comb study is presented in Table 4.9.

The IRR and the BCR from the cover comb study are high compared to past research returns calculated, while the NPVs are similar to some values calculated in past studies. This suggests these high returns are a reflection of the low cost of the research and extension compared to the benefits of the research, and the high returns from the research due to the rapid uptake of the technology and the size of the industry the technology applies to. The high returns calculated in this study can be attributed partly to the type of technology i.e. the cover comb is a simple, risk-reducing, easily adopted technology that is applicable to a large agricultural industry. In comparison returns from other research which may be more expensive or be adopted more slowly may be low or even negative. Scobie and Eveleens (1986) calculated a 30% return to aggregate research in New Zealand, indicating that although overall returns to research are high, they are considerably lower than the return from the cover comb study. Therefore the high returns from research such as the cover comb study more than compensate for research where returns are low, or where there are no direct financial benefits e.g. basic research.

**Table 4.9 : A summary of the returns[1] to research calculated in five cost-benefit analysis studies. (Numbers in brackets indicate the number of studies where results are reported for more than one study).**

| Study | Discount Rate | IRR (%) | NPV ($million) | BCR |
|---|---|---|---|---|
| **Cover comb technology[2]** | | | | |
| High Benefit Level, AR1 | 5% | 1330% | 49.22 | 115.69 |
| High Benefit Level, AR1 | 10% | 1330% | 38.00 | 76.02 |
| Low Benefit Level, AR1 | 5% | 584% | 23.07 | 54.76 |
| Low Benefit Level, AR1 | 10% | 584% | 17.68 | 35.91 |
| **CSIRO Entomology[3] (13)** | 5% | 19% | 0.1 - 372.8 | 4.4 |
| | 10% | 19% | 0.1 - 261.2 | 2.3 |
| **Bread wheat breeding[4]** | 5% | 64% | 27.72 | 10.8 |
| | 10% | 64% | 23.77 | 11.4 |
| **CSIRO Plant Division[5]** | | | | |
| Disease control/resistance (4) | 5% | | -1.8 - 179.2 | 0.8 - 18.5 |
| New varieties (4) | 5% | | 7.5 - 252.0 | 1.5 - 6.1 |
| Processing (2) | 5% | | 57.1 - 77.4 | 26.5 - 29.6 |
| **MIRINZ[6]** | | | | |
| Aujeskeys disease | 10% | -51% | -0.26 | |
| Aujeskeys disease | 5% | -51% | -0.42 | |
| Phenax (vaccine) | 10% | -40% | -0.42 | |
| Accelerated C&A[7] | 10% | 7% | -16.13 | |
| Accelerated C&A | 5% | 7% | 11.92 | |
| Low temperature rendering | 10% | 110% | 22.55 | |
| Loin boner | 10% | 33% | 3.92 | |

[1] Returns are presented as an internal rate of return (IRR) (%), a net present value (NPV) ($millions) and a benefit-cost ratio (BCR).
[2] Current study. NPV is in $1996.
[3] Marsden *et al* (1980). NPV is in $1975.
[4] Ralph (1993). NPV is in $1990.
[5] Bezar (1993). NPV is in $1993.
[6] FORST (1997). NPV is in $1995.
[7] C&A = conditioning and ageing.

## CONCLUSIONS

The returns from the investment in research and extension in cover comb shearing were very high (Tables 4.5 and 4.6), even when more conservative estimates of the benefits to the technology were applied. These high returns can be attributed mainly to the large sheep population that the results applied to, and to the rapid uptake of the technology. Where development was included (Table 4.8) returns were still high, although the IRR was lower, BCRs were similar and NPVs were higher. All cover comb sheep were included, in calculating the benefits to development, research and extension.

The size of the benefits as determined by the percentage reduction in losses had a big impact on the size of the returns, although they were still high at the lower level. Similarly, the adoption rate had an effect, although this was not as great as that of the size of the returns. A delay in the uptake of the technology would also have had an effect on the returns. The effect of an increase in the research costs was not large. Research depreciation was not considered to be an issue in this study as it was considered unlikely that the technology would be superseded in the next twenty years. However, high returns were calculated for all four different time periods included in the analysis, suggesting that even if the technology is superseded before 2020, the returns to research and extension will have been high.

Other benefits associated with cover comb shearing were not included in this analysis. The reduction in losses due to the greater protection from inclement weather after shearing with a cover comb was the only advantage included in the cost-benefit analysis. Other advantages include feed savings, a better spread of labour, a reduction in time spent moving sheep to shelter in adverse climatic conditions post-shearing, management flexibility, peace of mind, animal welfare and sales advantages. Some of these are intangible benefits which should be considered in research evaluation decisions. There was insufficient data to include some of these in the cost-benefit analysis e.g. feed savings, sales advantages. Some of these benefits were not the purpose for which the cover comb was designed e.g. sales advantages, demonstrating that all benefits (and possibly costs) will not necessarily be able to predicted in an *ex* *ante* analysis. Had all these benefits been included in the analysis the returns would have been greater.

A cost-benefit model for sensitivity analysis could be useful in *ex ante* research evaluation to identify the circumstances under which research would be worthwhile, and to identify the variables likely to have the greatest impact on returns to research and extension. The information gathering process used for the cost-benefit analysis, would also be useful as much of this information is already required in allocating research-funding.

# CHAPTER FIVE

# CONCLUSIONS AND RECOMMENDATIONS

Reduced Government spending on agricultural research in New Zealand in recent years, policy initiatives to increase private sector funding, and reduced expenditure on farm production research in favour of food processing or added value research, have all encouraged organisations involved in agricultural research or its funding to focus more closely on ways to maximise industry benefits from the allocation of limited research funds. An *ex ante* evaluation of potential research projects can be undertaken in order to devise the optimum portfolio of research funds; an *ex post* evaluation demonstrates the returns to on-farm agricultural research and can possibly be used to justify further investment in the sector concerned.

The objectives of this research were, first, to quantify the costs and the benefits associated with the development, evaluation and extension of cover comb technology and, second, to calculate the return on this investment. The cover comb is a relatively simple technology, whose development, research evaluation and extension are reasonably well-documented. Development costs were incurred by Sunbeam Corporation Ltd, and some of the research and extension costs were funded by an industry organisation (Wools of New Zealand). The cover comb generates financial advantages to farmers by reducing sheep losses associated with winter-spring shearing of sheep and possibly by conserving pasture when it is normally in short supply at those times of year.

The cover comb technology therefore provided the basis for developing a cost-benefit analysis model that could be applied to assess costs and benefits of other on-farm research opportunities related to wool production. The return on the investment by Wools of New Zealand in cover comb technology research was estimated to be positive and high relative to the return on other investment options.

The objectives of the study were largely met. Even though the study was *ex post*, an exact return to the total investment in cover comb technology could not be calculated because some input information could not be determined. The model was very sensitive to the percentage reduction in sheep losses, and the rate and level of adoption, and each of these factors had to be estimated. In addition, a sensitivity analysis was conducted with two adoption uptakes (an increase between 1989 and 2000, of 12.9%, and 9.5% of all sheep in New Zealand being shorn with a cover comb due to the research and extension), two levels of reduction in sheep losses (0.5% and 1%) and two discount rates (5% and 10%) in order to account for some of the uncertainty.

The estimated returns on the investment in cover comb research and extension were very high (Table 5.1), even where more conservative estimates of the benefits deived from the technology were applied, and development costs were included. Wools of New Zealand therefore obtained a very good return on the $109,554 it allocated to the research on behalf of its levy-paying wool growers.

**Table 5.1 : The returns[1] to research and extension on cover comb shearing technology.**

| | High Benefit Level[2] | | Low Benefit Level | |
|---|---|---|---|---|
| **Option** | **DR = 5%** | **DR = 10%** | **DR = 5%** | **DR = 10%** |
| **Adoption Rate 1[3]** | | | | |
| **IRR (%)** | 1330 | 1330 | 584 | 584 |
| **NPV ($m)** | 49.22 | 38.00 | 23.07 | 17.68 |
| **BCR** | 115.7 | 76.0 | 54.8 | 35.9 |
| **Adoption Rate 2** | | | | |
| **IRR (%)** | 1100 | 1100 | 485 | 485 |
| **NPV ($m)** | 34.92 | 27.06 | 15.99 | 12.30 |
| **BCR** | 82.4 | 54.4 | 38.3 | 25.3 |
| **Include Development[4]** | | | | |
| **IRR (%)** | 82.5 | | 47.2 | |
| **NPV ($m)** | 147.86 | | 58.98 | |
| **BCR** | 90.1 | | 36.5 | |

[1] Returns are presented as an internal rate of return (IRR) (%), a net present value (NPV) ($millions) and a benefit-cost ratio (BCR) for the period 1989 to 2020 (DR = discount rate).

[2] The high benefit level relates to a 1% reduction, and the low benefit level to a 0.5% reduction, in losses.

[3] Adoption rate 1 and adoption rate 2 refer to an increase between 1989 and 2000, of 12.9%, and 9.5% of all sheep in New Zealand being shorn with a cover comb due to the research and extension, respectively,

[4] All cover comb-shorn sheep were accounted for in calculating the benefits. The adoption rate with the research and extension was applied from 1989 to 2020. The return is calculated for the period 1972 to 2020.

The returns from the cover comb study are high compared to those calculated for other agricultural research (internal rates of return range between -51% to 440%, with most being between 20% and 50%; see Chapter 1, Past returns to agricultural research investment, and Table 4.9). The high returns reflect the relatively low cost of the research and extension activities for the cover comb, compared to the benefits accrued through the rapid uptake of the technology and its application to a large number of sheep. Net benefits per sheep were small ($0.467 and $0.229 for the two benefit levels), but overall benefits were high because of the industry's size. The high returns can also be attributed to the type of technology i.e. the cover comb is a simple, risk-reducing, easily adopted technology that is applicable to a large agricultural industry. High returns from more successful research, such as that on cover comb-shearing technology, can compensate for the low or negative returns from other more "risky" research, so that the overall return to a research portfolio is at an acceptable level.

The uptake of the cover comb following the research and extension was very rapid and this was an important factor in the cost-benefit analysis. A delay of three years in the uptake of the technology, for example, would have reduced the IRR from 1330% to 108%, and the NPV at the 5% discount rate from $52.22 million to $39.54 million. While this still represents a very high return, it also emphasises the importance of technology transfer in minimising the time lag between research and its commercial adoption.

A 1% increase in uptake of the cover comb for ewe shearing, at a 5% discount rate and a higher benefit level, gave an IRR of 468% and a NPV of $2.77 million; at the lower benefit level corresponding values were 90% and $6.09 million, respectively. Had an *ex ante* analysis been conducted prior to the cover comb experiments trials it could have been shown that only a small increase in technology uptake was required for the research and extension to be worthwhile. The size of the industry, as well as the rate of technology uptake, is therefore important in evaluating the returns to farm-level research. Identifying the population to which the research applies is an important step in calculating research returns e.g. whether research is targeted to all sheep farms, or to a segment of the sheep population.

Difficulties were experienced in obtaining data for some aspects of this study. This included quantifying the numbers of sheep shorn by class and under the different shearing policies, the likely reduction in sheep losses, the size of feed savings due to shearing with a cover comb rather than a conventional comb, and some components of research costs.

For the future evaluation of research it would be useful if some of these parameters were collected. In particular, the numbers of sheep shorn by class and by shearing policy are likely to be useful for on-farm research that impacts on wool production or its harvest. The New Zealand Meat and Wool Board Economic Service (NZMWBES) or Wools of New Zealand could record this information routinely.

Research costs were based on the research proposals and the "materials and methods" sections of the cover comb trial publications, rather than a record of actual research costs. There may therefore be some small discrepancies between the estimated and actual research costs incurred. However, this would have almost no effect on the final results. Nevertheless, a system to record actual research costs could be of use to Massey University and funding organisations if they intend to evaluate the returns on a particular piece of future research.

Wool industry returns beyond the farm gate were not included in this study. Wool harvested in the winter-spring tends to be stronger and whiter than that shorn later, and may also attract a better price due to timing of sales relative to demand. The uptake of cover comb technology is unlikely to alter the value of the wool output, unless large numbers of farmers adopt eight-month or pre-lamb shearing policies because of the availability of the cover comb. The model could be enhanced to include these off-farm costs and benefits of research, if this was required.

A number of benefits (and costs) to research are intangibles (i.e. items that cannot be quantified financially). Intangibles can be given a financial value, but some sort of subjective decision is still required e.g. how much are people willing to pay for "peace of mind"? These intangibles should be considered when cost-benefit analysis results are interpreted. In this study, possible benefits to farmers of cover comb technology not included in the cost-benefit analysis were: a better spread of labour; a reduction in time spent moving sheep to shelter if adverse climatic conditions occur post-shearing; management flexibility; "peace of mind"; animal welfare; and the ability to sell sheep sooner "off-the-shears". Such benefits (and costs) may not be known when preparing an *ex ante* evaluation of research, and for this reason the results from that approach are likely to be more conservative than those obtained from an *ex post* analysis.

The model developed for the *ex post* economic analysis of the cover comb research can be adapted to perform an *ex ante* analysis of proposed sheep industry on-farm research. Differential benefits and adoption rates can be applied across both the sheep farm regions and the different stock classes defined by the NZMWBES. This is useful where the uptake and benefits are expected to occur differentially across sectors of the sheep population e.g. sheep breeds or wool types. Depending on the research to be evaluated, some adaptation of the model may be required, which in turn may be dependent on data required for the model being known.

In conclusion, the *ex post* cost-benefit analysis showed industry investment in cover comb technology to be very profitable. The cover comb is a simple, risk-reducing, easily adopted technology that is applicable to a large segment of a large agricultural industry. Industry investment in research to develop technology with similar attributes is also likely to yield high returns. Adapting the model for *ex ante* evaluations of proposed research would be useful for determining which areas the wool industry should give highest priority to in the future.

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# APPENDIX I: DESCRIPTION OF THE RESEARCH TRIALS

Six cover comb research trials were conducted at Massey University between 1989 and 1995. These have been identified as Trials 1 to 6. A detailed description of the trials is provided in this Appendix.

Trial 1: Field trial conducted in 1989.
Trial 2: Calorimetry trial conducted in 1990.
Trial 3: Field trial conducted in 1992.
Trial 4: Calorimetry trial conducted in 1992.
Trial 5: Calorimetry trial conducted in 1995.
Trial 6: Field trial conducted in 1994/95.

# DESCRIPTION OF RESEARCH TRIAL ONE

**TRIAL 1:** Effect of method of pre-lamb shearing of ewes on pasture intake, rectal temperature, metabolic status, lamb birthweights and wool production (July - November 1989).

Note: Trial 1 and Trial 2 were published together, therefore the abstract is the same for each.


## ABSTRACT

Sheep shorn with a cover comb were compared with conventionally shorn sheep in two experiments. In the first experiment, ewe and lamb performance and some aspects of ewe physiology were measured with 60 Romney ewes which were shorn before lambing. In the second experiment, oxygen consumption by 12 Romney hoggets was measured before and after shearing in calorimeters at 10 degrees Celsius.

In the first experiment, herbage intake by ewes in the 3 weeks post-shearing was not affected by shearing method. There were no treatment effects on the liveweight of ewes, birthweight and growth rate of lambs nor on ewe wool production during the 2 months post-shearing. However on days 1 and 3 after shearing the plasma concentrations of non-esterified fatty acids and of 3-hydroxybutyrate were higher in ewes shorn with the conventional comb than in those shorn with the cover comb.

In the second experiment oxygen consumption was increased immediately after shearing , by 47% and 25% in the conventional and cover comb shorn ewes respectively. The difference between the two groups, which remained significant until day 12 post-shearing, decreased with time until it disappeared on day 22.

The results show that sheep shorn with the cover comb were significantly more resistant to cold conditions than those shorn with the conventional comb, particularly during the 3 days post-shearing. Use of the cover comb may offer a useful low cost method of reducing the effects of cold conditions after shearing, but its effects on mortality have not been demonstrated (Holmes *et al.*, 1992).


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# DESCRIPTION OF RESEARCH TRIAL TWO

**TRIAL 2:** Effect of shearing method on cold stress in sheep (August - November 1990).

Note: Trial 1 and Trial 2 were published together therefore, the abstract is the same for each.


## ABSTRACT

Sheep shorn with a cover comb were compared with conventionally shorn sheep in two experiments. In the first experiment, ewe and lamb performance and some aspects of ewe physiology were measured with 60 Romney ewes which were shorn before lambing. In the second experiment, oxygen consumption by 12 Romney hoggets was measured before and after shearing in calorimeters at 10 degrees Celsius.

In the first experiment, herbage intake by ewes in the 3 weeks post-shearing was not affected by shearing method. There were no treatment effects on the liveweight of ewes, birthweight and growth rate of lambs nor on ewe wool production during the 2 months post-shearing. However on days 1 and 3 after shearing the plasma concentrations of non-esterified fatty acids and of 3-hydroxybutyrate were higher in ewes shorn with the conventional comb than in those shorn with the cover comb.

In the second experiment oxygen consumption was increased immediately after shearing , by 47% and 25% in the conventional and cover comb shorn ewes respectively. The difference between the two groups, which remained significant until day 12 post-shearing, decreased with time until it disappeared on day 22.

The results show that sheep shorn with the cover comb were significantly more resistant to cold conditions than those shorn with the conventional comb, particularly during the 3 days post-shearing. Use of the cover comb may offer a useful low cost method of reducing the effects of cold conditions after shearing, but its effects on mortality have not been demonstrated (Holmes *et al.*, 1992).


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# DESCRIPTION OF RESEARCH TRIAL THREE

**TRIAL 3:** A comparison of cover and conventional comb shearing of ewes prior to lambing (November 1991 - November 1992).

**ABSTRACT** (Abbreviated)
The effects of pre-lamb shearing ewes with cover or standard comb, and of leaving ewes unshorn until after weaning , on their feed intake, productivity, and cold resistance were studied. Border Leicester x Romney ewes were divided into three groups balanced for pregnancy status, ewe age and liveweight. Two groups of ewes were shorn , by either cover comb or standard comb, on day 114 of pregnancy (P114) and one group left unshorn until weaning on day 84 of lactation (L84). Ewes were managed under the same conditions during pregnancy and lactation.

Ewes shorn pre-lamb by cover comb had lower mortality from shearing to lambing, and lower organic matter intakes and biting rates at P123-126 than ewes shorn by standard comb. These parameters did not differ between ewes shorn pre-lamb by cover comb and unshorn ewes except biting rate which was greater in the cover comb shorn group. Twenty days after shearing (P134), the liveweights of ewes were greater in the unshorn group than in the cover comb-shorn group ($P<0.05$), which was in turn heavier ($P<0.05$) than ewes shorn by standard comb. Midside clean wool growth rates were greater in standard comb- and cover comb-shorn ewes during the post-shearing period (to day 40 of lactation) than in unshorn ewes ($P<0.05$). Similarly, the yield and brightness of wool were superior ($P<0.05$) in pre-lamb shorn groups. Lamb liveweights at birth, docking and weaning, and lamb survival, were similar between shearing policies. Rectal temperature (RT) was significantly ($P<0.05$) lower in both pre-lamb shorn groups than in the unshorn group on day 3 post shearing (S3), but by S5 only the ewes shorn by standard comb had lower RT. The greater amount of residual wool in cover comb- vs standard comb shorn ewes provides a low cost practical method for reducing the two important disadvantages of pre-lamb shearing, namely increased cold-stress and feed intakes post-shearing (Dabiri *et al.*, 1995).

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# DESCRIPTION OF RESEARCH TRIAL FOUR

**TRIAL 4:** The effects of shearing by cover comb or conventional comb on the sheep's resistance to cold, windy and wet conditions (1992).


## ABSTRACT

The cover comb has been developed in New Zealand as a means of increasing residual fleece depth after shearing and so increasing the resistance of shorn sheep to cold stress.
The effects of shearing by cover comb and standard comb were studied over 2 days pre-shearing and 10 days post-shearing in eight pairs of non-pregnant, non -lactating 2-year-old ewes. Animals were housed and given a maintenance level of chaffed lucerne hay. One member of each pair was shorn with a cover comb, the other with a standard comb. Each pair was exposed to 'cold plus wind' (7 degrees C ambient temperature, 7km/hr air movement) followed by 'cold plus wind plus rain' (10 degrees C ambient temperature, 7km/hr air movement, wetting at a rate equivalent to 25mm/h rain from overhead sprinklers) in a calorimetry chamber on days S-3, S-2, S0 (day of shearing), S2, S6 and S10. Heat production immediately after shearing (S0) was proportionately 0.22 greater in ewes shorn by the standard comb under conditions of 'cold plus wind' and 0.38 greater under conditions of 'cold plus wind plus rain' than in their cover comb cohorts. Circulating concentrations of non-esterified fatty acids were substantially elevated on the day of shearing and 2 days thereafter in ewes shorn by the standard comb, indicating increased rates of body fat mobilization to support heat production in these ewes compared with those shorn by the cover comb. This was reflected in a 1.4 kg weight loss in the standard comb shorn ewes compared with a 0.4 kg liveweight gain in the cover comb-shorn group over the 10 days of the experiment. It was concluded that use of a cover comb will significantly reduce the risk of death from hypothermia in sheep shorn during winter and spring, and should facilitate an increase in the productivity of animals by allowing a greater proportion of food energy to be used for productive purposes (Dabiri *et al.*, 1995).


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# DESCRIPTION OF RESEARCH TRIAL FIVE

**TRIAL 5:** Effect of shearing by cover comb or blades on the resistance of sheep to cold, windy and wet conditions (April - August 1995).


## ABSTRACT

This study follows earlier research in 1991 and 1993 on cover vs. standard comb shearing and its purpose was to obtain quantitative data on the effects of shearing sheep with blades or a cover comb. Four pairs (total 8 sheep) of Romney mixed-age ewes were housed indoors for two weeks prior to the measurements of oxygen consumption. They were fed on chaffed lucerne hay, at a level equivalent to 1.2 times maintenance. The sheep were studied sequentially in pairs (one cover comb and one blades). Oxygen consumption was measured in two open circuit calorimeter chambers on days -3, -2, 0, 2, 6 and 10 with day 0 being day of shearing. On each measurement day, oxygen consumption was measured under two sets of climatic conditions (cold plus wind, followed by cold plus wind plus rain). During the measurement period each set of climatic conditions was held at a steady state. Fleece depth was measured on day -2, day 0 and day 10, relative to shearing. Liveweights were taken on days 0 and 10. Differences in liveweights, fleeceweight and liveweight gain of the ewes were not statistically significant. The rate of oxygen consumption (litres/kg$^{0.75}$ /hour) for cover comb and blade shorn-sheep was not significant during the cold+wind conditions although significance was approached ($P<0.08$) on day 6 post-shearing. However, when 'rain' was added to the weather treatment, the oxygen consumption of cover comb ewes was significantly ($P<0.05$) greater than that of their blade shorn counterparts on the day of shearing (1.47± 0.05 l/kg$^{0.75}$/hour vs 1.28 ± 0.05 l/kg$^{0.75}$/hour ), day 6 (1.29 ± 0.06 l/kg$^{0.75}$/hour vs 1.06 ± 0.06 l/kg$^{0.75}$/hour ), and day 10 post-shearing (1.25 ± 0.06 l/kg$^{0.75}$/hour vs 1.03 ± 0.06 l/kg$^{0.75}$/hour ). Blade shearing left almost twice the fleece stubble of a cover comb (11±4mm vs 5±4mm), however this difference was not significant. This difference was essentially maintained 10 days after shearing. From a practical view point the use of blades would only be worthwhile in terms of sheep survival where shearing coincided with a high risk of very cold, wet and windy conditions. (Burnham *et al.*, 1996)

In association with this trial, a small research project to quantify the wool stubble depth remaining on sheep shorn by different combs was conducted. Four sheep were each shorn with a cover comb, a Heiniger Big 10 comb, a Sunbeam Super 9 comb and two types of conventional combs. The area (cm$^2$) and greasy fleece weight (grams) remaining were measured, and the greasy fleece weight remaining was calculated (mg/mm$^2$) for each comb type. This was 8.75, 4.24, 3.06, 3.75, and 2.88 mg/mm$^2$ for the cover comb, the Super 9 comb, the Big 10 comb and the two conventional combs, respectively. The stubble depth left by the cover comb was significantly greater than that left by the other combs ($P<0.001$). The length of stubble left by the other combs was not significantly different.


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# DESCRIPTION OF RESEARCH TRIAL SIX

**TRIAL 6:** Pasture management to minimise the detrimental effects of pre-lamb shearing (July 1994 - December 1995).


## ABSTRACT

The purpose of this study was to examine whether the performance of pre-lamb shorn sheep is influenced by pasture allowance in the immediate post-shearing period and whether the relationship between performance and pasture allowance differed according to whether the ewes were shorn by standard comb (SC) or cover comb (CC). The trial was replicated across two years to to allow for climatic variations that occurred between seasons which could markedly affect results. Fifty four ewes were used in each year in a 3x3x2 factorial design with three shearing treatments (ST) (SC, CC, and unshorn), three sward surface height (SSH) (nominal 3, 5, and 7 cm) and two pregnancy-status groups (single and twin). There was an interaction between ST and SSH which resulted in liveweight gains during the period from pregnancy day 115 (P115) to P135 of 275, 613 and 4518 g; 1557, 2314 and 3997 g; and 3623, 2894 and 3997 g for SC, CC and unshorn (control) ewes set-stocked on 3, 5 and 7 cm SSH, respectively. There were no effects of ST or SSH on lamb weaning weight, ewe wool growth rate or mean fibre diameter. There was no interaction between ST and SSH for lamb birth weight (LBW), but the LBW of lambs born to SC ewes (4.9±0.1 kg) was significantly heavier ($P<0.05$) than those of lambs born to unshorn (control) ewes (4.3±0.1 kg). Rectal temperatures of SC or CC ewes were significantly lower ($P<0.05$) than those of unshorn (control) ewes on day2 following shearing (S2), and on S4, S8, and S20. Pasture allowance, however, did not affect rectal temperatures of shorn ewes. Blood concentrations of glucose, NEFA or 3-OHB were not influenced by ST or SSH throughout the days of measurement. There were no effects of ST or SSH on ewe organic matter intake (OMI), except on the 2nd day following shearing where the OMIs of ewes set-stocked on 3 cm (941±147 g) were significantly lower than those ewes grazing 5 cm (1628±101 g) or 7 cm (1349±135 g) SSH pasture. The results suggested that hypothermia, as determined by rectal temperatures and induced by pre-lamb shearing, cannot be avoided by pasture management. Neither the use of a standard comb for pre-lamb shearing, nor a low pasture allowance (3 cm SSH) affected short- or long-term production parameters (Husain, 1996).


## KEY PERSONNEL

| | |
|---|---|
| Assoc. Prof. S.T. Morris | Department of Animal Science |
| Prof. W.J. Parker | Department of Agricultural and Horticultural Systems Management |
| Prof. S.N. McCutcheon | Department of Animal Science |
| Mr M.H. Husain | Department of Animal Science |
| Mr D. Burnham | Department of Animal Science |

## PUBLICATIONS


Husain, M.H. (1996). Pasture management to minimise the detrimental effects of pre-lamb shearing. M Agr Sc Thesis, Massey University, Palmerston North.

Husain, M.H., Morris, S.T., McCutcheon, S.N. and Parker, W.J. (1997). Pasture management to minimise the detrimental effects of pre-lamb shearing. *New Zealand Journal of Agricultural Research* (submitted).

# APPENDIX II: COSTS ASSOCIATED WITH THE RESEARCH TRIALS

A breakdown of some of the costs associated with each of the research trials is provided in this Appendix. The assumptions made in calculating the personnel costs and the shearing costs are outlined below. This is followed by a condensed summary of the costs before details for individual trials are presented.

## ASSUMPTIONS MADE IN CALCULATING RESEARCH TRIAL COSTS

**Personnel Costs**

1. The mid point of the pay scale range for current salaries was used. These were:

| | |
|---|---|
| Senior Lecturer | $62000 |
| Associate Professor | $73000 |
| Professor | $91000 |
| Technician Grade 7 | $26420 |

2. The opportunity cost of postgraduate student's time has been assessed using technician salary scales.

3. It was assumed that Masterate students spend 50% of their course on research, of which 50% would be a learning experience, and 50% would be in carrying out research that a technician would otherwise have to be employed to do.

   Student A did a 2 year Masterate and was involved in 2 trials. Therefore 3 months per trial has been allowed in the calculations.

   Student B did a 2 year Masterate and was involved in a 2 year trial. Therefore 3 months per year has been allowed in the calculations.

4. It was assumed that Ph D students spend 100% of their course on research, of which 50% would be a learning experience, and 50% would be in carrying out research that a technician would otherwise have to be employed to do.

   Student C did a 4 year Ph D and was involved in 4 trials. Therefore 6 months per trial, for the 2 cover comb trials he was involved in has been allowed in the calculations.

**Shearing Costs**

1. In most of the trials Wools of NZ shore the sheep free or at a low cost. The opportunity cost of shearing was calculated at $1.60 per sheep for all trials. It would be uneconomic from a commercial point of view to shear only a few sheep, and where this has occurred an opportunity cost of the Wools of NZ shearers time in travelling (at $30/hr) and vehicle expenses (56c/km based on the official IRD rate used by Massey University for a 1601 to 2000cc vehicle) have been included.

| A summary of the proposed research trial costs for the six cover comb shearing trials. | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | RESEARCH COSTS (PROPOSED) | | | | |
| Item | TRIAL 1 | TRIAL 2 | TRIAL 3 | TRIAL 4 | TRIAL 5 | TRIAL 6 | TOTAL |
| | 1989 | 1990 | 1992 | 1992 | 1995 | 1994/95 | |
| **Scientists Salaries** | | | | | | | |
| Massey University | 1800 | 6000 | 6000 | 2000 | 3575 | 16800 | 36175 |
| Wools of NZ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Technician Salaries** | | | | | | | |
| Massey University | 462 | 0 | 365 | 2507 | 1250 | 2500 | 7084 |
| Wools of NZ | 462 | 4000 | 1162 | 2507 | 2641 | 0 | 10772 |
| Other | 0 | 0 | 442 | 0 | 0 | 0 | 442 |
| **Overheads** | | | | | | | |
| Massey University | 463 | 1800 | 3385 | 2254 | 0 | 9650 | 17552 |
| Wools of NZ | 0 | 2700 | 705 | 1253 | 2425 | 0 | 7083 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Research Unit Costs** | | | | | | | |
| Massey University | 75 | 0 | 0 | 0 | 0 | 0 | 75 |
| Wools of NZ | 75 | 0 | 2700 | 285 | 140 | 2000 | 5200 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Shearing Costs** | | | | | | | |
| Massey University | 30 | 0 | 504 | 0 | 0 | 0 | 534 |
| Wools of NZ | 30 | 0 | 432 | 0 | 0 | 0 | 462 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Consumables** | | | | | | | |
| Massey University | 33 | 0 | 30 | 0 | 0 | 0 | 63 |
| Wools of NZ | 32 | 0 | 0 | 300 | 150 | 12528 | 13010 |
| Other | 0 | 0 | 220 | 0 | 0 | 0 | 220 |
| **Calorimetry Consumables** | | | | | | | |
| Massey University | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wools of NZ | 0 | 560 | 0 | 500 | 250 | 0 | 1310 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Other Equipment** | | | | | | | |
| Massey University | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wools of NZ | 0 | 0 | 0 | 2480 | 0 | 0 | 2480 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Sample Analysis** | | | | | | | |
| Massey University | 62 | 0 | 405 | 0 | 0 | 0 | 467 |
| Wools of NZ | 62 | 0 | 247 | 0 | 383 | 4082 | 4774 |
| Other | 0 | 0 | 1560 | 0 | 0 | 0 | 1560 |
| **Computing/Data Analysis** | | | | | | | |
| Massey University | 50 | 0 | 0 | 0 | 0 | 0 | 50 |
| Wools of NZ | 50 | 0 | 500 | 0 | 350 | 1000 | 1900 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Travel** | | | | | | | |
| Massey University | 25 | 0 | 0 | 0 | 0 | 0 | 25 |
| Wools of NZ | 25 | 0 | 0 | 0 | 0 | 200 | 225 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Animal Feed** | | | | | | | |
| Massey University | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wools of NZ | 0 | 420 | 0 | 500 | 250 | 0 | 1170 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Oportunity Cost** | | | | | | | |
| Massey University | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wools of NZ | 0 | 0 | 380 | 0 | 0 | 0 | 380 |
| Other | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Costs** | | | | | | | |
| Massey University | 3000 | 7800 | 10689 | 6761 | 4825 | 28950 | 62025 |
| Wools of NZ | 736 | 7680 | 6126 | 7825 | 6589 | 19810 | 48766 |
| Other | 0 | 0 | 2222 | 0 | 0 | 0 | 2222 |
| **TOTAL OVERALL COST** | 3736 | 15480 | 19037 | 14586 | 11414 | 48760 | 113013 |
| | All costs exclusive of GST | | | | | | |

# RESEARCH COSTS: TRIAL ONE

**TRIAL 1:** Effect of method of pre-lamb shearing of ewes on pasture intake, rectal temperature, metabolic status, lamb birthweights and wool production (July - November 1989).

| | | | | |
|---|---|---|---|---|
| Personnel | | | | |
| | Assumed 3% * $62000 | | | $1860 |
| | Person F 25% * $26420 | | | $6605 |
| Operating Costs | | | | |
| | Shearing Costs | | | |
| | | 60 sheep @ $1.60/hd | $96 | |
| | | Travel 50km * $0.56/km | $28 | |
| | | Travel time 1hour @ $30/hr | $30 | $ 154 |
| | Lamb birthweight recording | | | |
| | | 20 hrs * $11.50/hr | | $ 230 |
| | Rectal temperature recording | | | |
| | | 60 ewes * $0.65/ewe * 7 | | $ 273 |
| | Weighing of ewes | | | |
| | | 2 hrs * $11.50/hr * 3 | | $ 69 |
| | Wool sample preparation | | | |
| | | 60 ewes * $4.00/ewe * 2 | | $ 480 |
| | Fleece Analysis - Yield | | | |
| | | 60 samples+2 bulk samples * $2.00/sample | | $ 124 |
| | Consumables | | | |
| | | 80 lamb tags * $0.25/tag | | $ 20 |
| | | 3 thermometers * $15 | | $ 45 |
| | Chromium capsules $12.00 * 20 sheep | | | $ 240 |
| | Faecal sampling 20 hrs * $11.50/hr | | | $ 230 |
| | Faecal Chromium Analysis | | | |
| | | 60 samples * $22.05/sample | | $1323 |
| | Digestibility Analysis 3 samples * $22.30 | | | $ 67 |
| | Total Nitrogen Analysis 3 samples * $21.75 | | | $ 65 |
| | Digestibility analysis consumables | | | $ 38 |
| | Blood sampling | | | |
| | | 348 samples * 15/hr * $11.50/hr | | $ 267 |
| | | Equipment 348 samples *$0.915 | | $ 318 |
| | | Non-esterified fatty acid (NEFA) analysis 348 * $3.92 | | $1364 |
| | | 3-hydroxybutyrate analysis 348 * $3.80 | | $1322 |
| | | Urea analysis 348 * $3.20 | | $1114 |
| | | Creatinine analysis 348 * $2.94 | | $1023 |
| | | Glucose analysis 348 * $2.93 | | $1020 |
| | Transport. Motorbike hire | | | $ 54 |
| | Computing | | | $ 100 |
| | | | | $9940 |
| Equipment Depreciation | | | | |
| | Computer | | | |
| | | $2600 * 3% M U Staff * 0.33 | | $ 26 |
| | | $2600 * 10% Post Grad * 0.33 | | $ 86 |
| | | | | $112 |
| Extraordinary costs | | | | |
| | Sheep and Beef Cattle Research Unit (SBCRU) | | | |
| | | 60 sheep * 8.3 weeks * $0.75/week | | $ 374 |

# RESEARCH COSTS: TRIAL TWO

**TRIAL 2:** Effect of shearing method on cold stress in sheep (August - November 1990).

| | | | | |
|---|---|---|---|---|
| Personnel | | | | |
| | Person D | 8% * $73000 | | $ 5840 |
| | Person E | 16% * $26420 | | $ 4227 |
| | | | | $10067 |
| | Person F | 25% * $26420 | | $6605 |
| Operating Costs | | | | |
| | Calorimetry consumables | | | |
| | | 16 weeks * 7days/week * $5/day | | $ 560 |
| | Silica gel 15 kg * $15/kg | | | $ 225 |
| | Lucerne chaff | | | |
| | | 12 sheep * 1.5kg/day * 40 days * $1.25/kg | | $ 900 |
| | Data analysis and computing | | | $ 200 |
| | Shearing Costs | | | |
| | | 12 sheep @ $1.60/hd | $19 | |
| | | Travel 50km * $0.56/km | $28 | |
| | | Travel time 1hour @ $30/hr | $30 | $ 77 |
| | | | | $1962 |
| Equipment Depreciation | | | | |
| | Computer | | | |
| | | $2600 * 24% M U Staff * 0.33 | | $206 |
| | | $2600 * 10% Post Grad * 0.33 | | $ 86 |
| | | | | $292 |
| Extraordinary costs | | | | |
| | Animal Physiology Unit (APU) charges | | | |
| | | 65 animal weeks * $50/animal week | | $3250 |

Note: Proposal was for 10 sheep, 12 sheep were used in the trial.

# RESEARCH COSTS: TRIAL THREE

**TRIAL 3:** A comparison of cover and conventional comb shearing of ewes prior to lambing (November 1991 - November 1992).

Personnel

| | | |
|---|---|---|
| Person A | 5% * $91000 | $4550 |
| Person C | 3% * $62000 | $1860 |
| Person B | 2% * $91000 | $1820 |
| | | $8230 |
| Person G | 50% * $26420 | $13210 |

Operating Costs

| | |
|---|---|
| Ewe weighing 2400 ewes * $0.26/ewe | $ 624 |
| Fleece recording | |
| Weighing 780 fleeces * $0.69c/fleece | $ 538 |
| Midside sample 90 ewes * $1.35/ewe *3 | $ 365 |
| Fleece Analysis | |
| Midside 270 samples * $1.50/sample | $ 405 |
| Fleece 90 samples * $2.74/sample | $ 247 |
| Consumables (bags) | $ 30 |
| Chromium capsules $12 * 60 sheep | $ 720 |
| Faecal sampling 60 hrs * $12/hr | $ 720 |
| Faecal Chromium Analysis | |
| 120 samples * $22.05/sample | $2646 |
| Digestibility Analysis 6 samples * $22.30 | $ 134 |
| Digestibility analysis consumables | $ 50 |
| Shearing | |
| Nov 300 ewes @ $1.60 | $ 480 |
| July 200 ewes @ $1.60 | $ 320 |
| Nov 280 ewes @ $1.60 | $ 448 |
| Opportunity cost-wool $0.80/kg * 2.5kg * 190 ewes | $ 380 |
| Data Analysis | $ 500 |
| | $8607 |

Equipment Depreciation

| | |
|---|---|
| Computer | |
| $2600 * 10% M U Staff * 0.33 | $ 86 |
| $2600 * 10% Post Grad * 0.33 | $ 86 |
| | $ 172 |

Extraordinary costs

| | |
|---|---|
| SBCRU charges | |
| 300 ewes * 6 months * $0.75/su/wk | $5850 |
| 300 tags * $2.00 | $ 600 |
| Pregnancy Diagnosis of ewes | $ 315 |
| | $6765 |

Note : Data analysis is for trials 3 and 4.

# RESEARCH COSTS: TRIAL FOUR

**TRIAL 4:** The effects of shearing by cover comb or conventional comb on the sheep's resistance to cold, windy and wet conditions (1992).

| | | | |
|---|---|---|---|
| Personnel | | | |
| | Person D 3% * $73000 | | $2190 |
| | Person G 50% * $26420 | | $13210 |
| Operating Costs | | | |
| | Feeding and cleaning | | |
| | 100 days * 1 hr/day * $11.50/hr | | $1150 |
| | Measurements | | |
| | 8 pairs * 6 days * 7 hours/day * $11.50/hr | | $3864 |
| | Equipment | | |
| | Hoods 2 * $1000 | | $2000 |
| | Fans 4 * $120 | | $ 480 |
| | Silica gel 20 kg * $15/kg | | $ 300 |
| | Calorimetry consumables | | $ 500 |
| | Lucerne chaff 400kg * $1.25/kg | | $ 500 |
| | Shearing Costs | | |
| | 16 sheep @ $1.60/hd | $26 | |
| | Travel 50km * $0.56/km | $28 | |
| | Travel time 1hour @ $30/hr | $30 | $ 84 |
| | Blood sampling | | |
| | 96 samples * 15/hr * $11.50/hr | $ 74 | |
| | Equipment 96 samples * $0.915 | $ 88 | |
| | NEFA analysis 96 * $3.92 | $376 | |
| | Glucose analysis 96 * $2.93 | $281 | $ 819 |
| | | | $ 9613 |
| Equipment Depreciation | | | |
| | Computer | | |
| | $2600 * 3% M U Staff * 0.33 | | $ 26 |
| | $2600 * 10% Post Grad * 0.33 | | $ 86 |
| | | | $ 112 |
| Extraordinary costs | | | |
| | APU charges | | |
| | 57 animal weeks * $50/animal week | | $ 2850 |

Note: Data analysis costs and computing costs are included in those for trial 3.

# RESEARCH COSTS: TRIAL FIVE

**TRIAL 5:** Effect of shearing by cover comb or blades on the resistance of sheep to cold, windy and wet conditions (April - August 1995).

Personnel

| | | | |
|---|---|---|---|
| Person D | 3% * $73000 | | $2190 |
| Person A | 3% * $91000 | | $2730 |
| Person C | 3% * $62000 | | $1860 |
| Person E | 5% * $26420 | | $1321 |
| | | | $8101 |

Operating Costs

| | | |
|---|---|---|
| Feeding and cleaning | | |
| 30 days * 1.5 hrs/day * $11.50/hr | | $ 517 |
| Measurements | | |
| 4 pairs * 6 days * 7 hrs/day * $11.50/hr | | $1932 |
| Data analysis and project administration | | $ 350 |
| Silica gel 10 * $15 | | $ 150 |
| Calorimetry consumables | | $ 250 |
| Lucerne chaff 200kg * $1.25/kg | | $ 250 |
| Shearing Costs | | |
| 8 sheep @ $1.60/hd | $13 | |
| Travel 50km * $0.56/km | $28 | |
| Travel time 1hour @ $30/hr | $30 | $ 71 |
| #Wool measurements | | |
| 4 sheep * 50 mins/sheep * $11.50/hr | | $ 38 |
| #Analysis of wool samples | | |
| 10 mins/sample * 40 samples * $11.50/hr | | $ 77 |
| #Shearing Costs | | |
| 4 sheep @ $1.60/hd | | $ 6 |
| | | $ 3641 |

Equipment Depreciation

Computer $2600 * 14% M U Staff * 0.33 $ 120

Extraordinary costs

| | |
|---|---|
| APU charges | |
| 28 animal weeks * $50/week | $ 1400 |

Note: # Trial using 4 sheep to measure the 'quantification of wool stubble depth remaining on sheep shorn by different combs and the blades'.

# RESEARCH COSTS: TRIAL SIX

**TRIAL 6:** Pasture management to minimise the detrimental effects of pre-lamb shearing (July 1994 - December 1995).

**This trial was conducted over 2 years. Costs below relate to costs per year.**

| | | | | |
|---|---|---|---|---|
| Personnel | | | | |
| | Person C | 6% * $62000 | | $ 3720 |
| | Person A | 4% * $91000 | | $ 3640 |
| | Person B | 4% * $91000 | | $ 3640 |
| | Person E | 5% * $26420 | | $ 1321 |
| | | | | $12321 |
| | Person H | 25% * $26420 | | $6605 |
| Operating Costs | | | | |
| | Data analysis/computing | | | $ 500 |
| | Analysis of wool samples | | | $ 500 |
| | Hormone analysis | | | |
| | $3.95/sample * 54 sheep* 6 occasions | | | $ 1280 |
| | Laboratory analysis-feed intake | | | |
| | consumables | | | |
| | $22.05 * 54 sheep * 8 occasions | | | $ 9526 |
| | field collection | | | $ 750 |
| | Travel | | | $ 100 |
| | Shearing Costs | | | |
| | 54 sheep @ $1.60/hd | | $ 86 | |
| | Travel 50km * 56c/km | | $ 28 | |
| | Travel time 1hour @ $30/hr | | $ 30 | $ 144 |
| | Chromium capsules $12 * 54 sheep | | | $ 648 |
| | | | | $13448 |
| Equipment Depreciation | | | | |
| | Computer | | | |
| | $2600 * 19% M U Staff * 0.33 | | | $163 |
| | $2600 * 10% Post Grad * 0.33 | | | $ 86 |
| | | | | $249 |
| Extraordinary costs | | | | |
| | Ruminant Research Unit charges | | | |
| | $50/su/yr * 54 su * 0.50 years | | | $ 1350 |

# APPENDIX III: CONVERSION OF DEVELOPMENT COSTS INTO 1996 NZ$

**Consumer Price Index (CPI) and Exchange Rates used in the Calculation of Development Costs. (CPI Base Year (1993) = 1000)**

| Year | Index | Exchange Rate (NZ$1) |
|---|---|---|
| 1971 | 121 | A$1.0020 |
| 1972 | 127 | A$0.9395 |
| 1994 | 1028 | A$0.8431 |
| 1995 | 1058 | |

Years given are for the quarter ended December. The CPI for January 1972 is therefore that for quarter ended December 1971.

$$1972\ A\$17{,}500 = \frac{1058}{121} \times \frac{17500}{1.002} = 1996\ NZ\$152{,}711$$

$$1973\ A\$17{,}500 = \frac{1058}{127} \times \frac{17500}{.9395} = 1996\ NZ\$155{,}175$$

$$1995\ A\$200{,}000 = \frac{1058}{1028} \times \frac{200000}{.8276} = 1996\ NZ\$248{,}715$$

**Sources of Information:**

CPI - Statistics NZ, 1995: NZ Official Year Book . 98th edition. Statistics New Zealand. Wellington.

Exchange Rates 1972 and 1973 - Statistics NZ, 1972 and 1973: N Z Official Year Book. 77th and 78th editions. Statistics New Zealand. Wellington.

Exchange Rate 1995 - Statistics New Zealand, 1995: Key Statistics, March 1995. Statistics New Zealand. Wellington.

# APPENDIX IV: PUBLIC GOOD SCIENCE FUND (PGSF) SPREADSHEETS FOR THE SIX TRIALS.

This Appendix includes the output of the PGSF spreadsheets used in calculating the research trial costs for the six trials. The objective number given on the spreadsheet output relates to the trial number i.e. Objective 1 relates to Trial 1.

# PGSF Spreadsheet

## 1. Personnel

| | Salary pa ($) Year 1 | Year 2 | Year 3 | | Fraction of time spent on objective Year 1 | Year 2 | Year 3 | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Existing Staff** | | | | | | | | | | | |
| **A** Person A | $62,000 | | | x | 0.030 | | | = | $1,860 | | |
| **B** Person B | | | | x | | | | = | | | |
| **C** Person C | | | | x | | | | = | | | |
| **D** Person D | | | | x | | | | = | | | |
| **E** Person E | | | | x | | | | = | | | |
| **F** Person F | $26,420 | | | x | 0.250 | | | = | $6,605 | | |
| **G** Person G | | | | x | | | | = | | | |
| **H** Person H | | | | x | | | | = | | | |
| | Total Existing Staff Salary Component | | | | | | **Box A** | | **$8,465** | | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | 1.71% | | | x | $8,465 | | | = | $145 | | |
| Superannuation | 4.5% | | | x | $8,465 | | | = | $381 | | |
| **New Staff** | | | | | | | | | | | |
| **I** | | | | x | | | | = | | | |
| **J** | | | | x | | | | = | | | |
| **K** | | | | x | | | | = | | | |
| **L** | | | | x | | | | = | | | |
| **M** | | | | x | | | | = | | | |
| **N** | | | | x | | | | = | | | |
| **O** | | | | x | | | | = | | | |
| **P** | | | | x | | | | = | | | |
| | Total New Staff Salary Component | | | | | | **Box B** | | | | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | 1.71% | | | x | | | | = | | | |
| Superannuation | 4.5% | | | x | | | | = | | | |
| Recruitment/Advertising & Relocation Costs | 2.2% | | | x | | | | = | | | |
| **Salary Component for Existing and New Staff** | | | | | | | **Box C** | | **$8,465** | | |
| **Total Associated Personnel Costs** | | | | | | | **Box D** | | **$526** | | |
| **TOTAL PERSONNEL COSTS** | | | | | | | **Box E** | | **$8,991** | | |

## 2. General Operating Costs

| | | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|
| Travel: | Domestic | = | . | . | |
| | International | = | | | |
| Conference Fees | | = | | | |
| Accommodation | | = | | | |
| Fieldwork Costs: | Accommodation | = | | | |
| | Per Diem | = | | | |
| Materials and Consumables | | = | $9,840 | . | |
| Computing Costs, S'ware Development | | = | $100 | . | |
| Report Preparation Costs | | = | | | |
| Printing, Photocopying and Photographic | | = | | | |
| Library Costs | | = | | | |
| Telephone, Tolls, Facsimile | | = | | | |
| Legal Costs | | = | | | |
| Health and Safety costs | | = | | | |
| Equipment (individual items less than $5000) | | = | | | |
| External Consultants | | = | | | |
| Other Operating Costs | | = | | | |

**TOTAL GENERAL OPERATING COSTS** **Box F** **$9,940**

## 3. Premises Costs

| | *Proportion* | | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|---|
| Lab Intensive Research | 0.50 | 0.057 x | $8,465 | = | $241 | | |
| Field-work Research | | 0.040 x | $8.465 | = | | | |

**TOTAL PREMISES COSTS** **Box G** **$241**

## 4. Equipment Depreciation

| | Equipment Cost | | Fraction of Time Used Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|
| Computers | $2,600 | x 0.33 x | 0.130 | | | $112 | | |
| | | x 0.33 x | | | | | | |
| | | x 0.33 x | | | | | | |
| Computer Driven Equipment | | x 0.20 x | | | | | | |
| | | x 0.20 x | | | | | | |
| | | x 0.20 x | | | | | | |
| Other Equipment | | x 0.10 x | | | | | | |
| | | x 0.10 x | | | | | | |
| | | x 0.10 x | | | | | | |

| | Cost per hour | | No of hours used Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|
| Equipment Rental | | x | | | |
| Equipment Maintenance | | = | | | |

**TOTAL EQUIPMENT DEPRECIATION & RENTAL** **Box H** **$112**

## 5. Overheads

| | | Staff Costs | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|
| 1.00 | x | $8,465 | = | $8,465 | | |

**TOTAL OVERHEADS** **Box I** **$8,465**

## 6. Extraordinary Costs

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| Research Unit/Farm Costs | = | $374 | | |
| Patenting Costs | = | | | |
| Computer Software Acquisition | = | | | |
| Access to Special Proprietary Databases | = | | | |
| Access to Special Equip & Services | = | | | |
| Casual Assistance for Extensive Fieldwork | = | | | |
| "Koha" for Marae Visits etc | = | | | |
| Staff Training Costs | = | | | |
| Laboratory remodelling | = | | | |
| Other Extraordinary Costs | = | | | |

**TOTAL EXTRAORDINARY EXPENSES** **Box J** **$374**

## SUMMARY FOR OBJECTIVE

| | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| Personnel Costs | $8,991 | | |
| General Operating Costs | $9,940 | | |
| Premises Costs | $241 | | |
| Equipment Depreciation & Rental | $112 | | |
| Overheads | $8,465 | | |
| Extraordinary Expenses | $374 | | |

**Sub Total** **Box K** **$28,122**

GST 12.5% x $28,122 = $3,515

**TOTAL COST COST OF OBJECTIVE** **$31,638**

# PGSF Spreadsheet

## 1. Personnel

| | Salary pa ($) Year 1 | Year 2 | Year 3 | | Fraction of time spent on objective Year 1 | Year 2 | Year 3 | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Existing Staff** | | | | | | | | | | | |
| **A** Person A | | | | x | | | | = | | | |
| **B** Person B | | | | x | | | | = | | | |
| **C** Person C | | | | x | | | | = | | | |
| **D** Person D | $73,000 | | | x | 0.080 | | | = | $5,840 | | |
| **E** Person E | $26,420 | | | x | 0.160 | | | = | $4,227 | | |
| **F** Person F | $26,420 | | | x | 0.250 | | | = | $6,605 | | |
| **G** Person G | | | | x | | | | = | | | |
| **H** Person H | | | | x | | | | = | | | |
| | Total Existing Staff Salary Component | | | | | | **Box A** | | **$16,672** | | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | | 1.71% | | x | $16,672 | | | = | $285 | | |
| Superannuation | | 4.5% | | x | $16,672 | | | = | $750 | | |
| **New Staff** | | | | | | | | | | | |
| **I** | | | | x | | | | = | | | |
| **J** | | | | x | | | | = | | | |
| **K** | | | | x | | | | = | | | |
| **L** | | | | x | | | | = | | | |
| **M** | | | | x | | | | = | | | |
| **N** | | | | x | | | | = | | | |
| **O** | | | | x | | | | = | | | |
| **P** | | | | x | | | | = | | | |
| | Total New Staff Salary Component | | | | | | **Box B** | | | | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | | 1.71% | | x | | | | = | | | |
| Superannuation | | 4.5% | | x | | | | = | | | |
| Recruitment/Advertising & Relocation Costs | | 2.2% | | x | | | | = | | | |
| **Salary Component for Existing and New Staff** | | | | | | | **Box C** | | **$16,672** | | |
| **Total Associated Personnel Costs** | | | | | | | **Box D** | | **$1,035** | | |
| **TOTAL PERSONNEL COSTS** | | | | | | | **Box E** | | **$17,708** | | |

## 2. General Operating Costs

| | | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|
| Travel: | Domestic | = | | | |
| | International | = | | | |
| Conference Fees | | = | | | |
| Accommodation | | = | | | |
| Fieldwork Costs: | Accommodation | = | | | |
| | Per Diem | = | | | |
| Materials and Consumables | | = | $1,762 | | |
| Computing Costs, S'ware Development | | = | $200 | | |
| Report Preparation Costs | | = | | | |
| Printing, Photocopying and Photographic | | = | | | |
| Library Costs | | = | | | |
| Telephone, Tolls, Facsimile | | = | | | |
| Legal Costs | | = | | | |
| Health and Safety costs | | = | | | |
| Equipment (individual items less than $5000) | | = | | | |
| External Consultants | | = | | | |
| Other Operating Costs | | = | | | |
| **TOTAL GENERAL OPERATING COSTS** | **Box F** | | **$1,962** | | |

## 3. Premises Costs

| | *Proportion* | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|
| Lab Intensive Research | 0.057 x | $16,672 | = | | | |
| Field-work Research | 0.040 x | $16,672 | = | | | |
| **TOTAL PREMISES COSTS** | | **Box G** | | | | |

## 4. Equipment Depreciation

| | Equipment Cost | | Fraction of Time Used Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|
| Computers | $2,600 x | 0.33 x | 0.340 | | | $292 | | |
| | x | 0.33 x | | | | | | |
| | x | 0.33 x | | | | | | |
| Computer Driven Equipment | x | 0.20 x | | | | | | |
| | x | 0.20 x | | | | | | |
| | x | 0.20 x | | | | | | |
| Other Equipment | x | 0.10 x | | | | | | |
| | x | 0.10 x | | | | | | |
| | x | 0.10 x | | | | | | |
| | *Cost per hour* | | *No of hours used* Year 1 | Year 2 | Year 3 | | | |
| Equipment Rental | | x | | | | | | |
| Equipment Maintenance | | = . | | . | . | . | . | . |

**TOTAL EQUIPMENT DEPRECIATION & RENTAL** **Box H** **$292**

## 5. Overheads

| | Staff Costs | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|
| 1.00 x | $16,672 | = | $16,672 | | |

**TOTAL OVERHEADS** **Box I** **$16,672**

## 6. Extraordinary Costs

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| Research Unit/Farm Costs | = | $3,250 | | |
| Patenting Costs | = | | | |
| Computer Software Acquisition | = | | | |
| Access to Special Proprietary Databases | = | | | |
| Access to Special Equip & Services | = | | | |
| Casual Assistance for Extensive Fieldwork | = | | | |
| "Koha" for Marae Visits etc | = | | | |
| Staff Training Costs | = | | | |
| Laboratory remodelling | = | | | |
| Other Extraordinary Costs | = | | | |
| **TOTAL EXTRAORDINARY EXPENSES** | **Box J** | **$3,250** | | |

## SUMMARY FOR OBJECTIVE

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| Personnel Costs | | $17,708 | | |
| General Operating Costs | | $1,962 | | |
| Premises Costs | | | | |
| Equipment Depreciation & Rental | | $292 | | |
| Overheads | | $16,672 | | |
| Extraordinary Expenses | | $3,250 | | |
| **Sub Total** | **Box K** | **$39,883** | | |
| GST 12.5% x $39,883 | = | $4,985 | | |
| **TOTAL COST COST OF OBJECTIVE** | | **$44,869** | | |

## 1. Personnel

| | Salary pa ($) Year 1 | Year 2 | Year 3 | | Fraction of time spent on objective Year 1 | Year 2 | Year 3 | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Existing Staff** | | | | | | | | | | | |
| **A** Person A | $91,000 | | | x | 0.050 | | | = | $4,550 | | |
| **B** Person B | $91,000 | | | x | 0.020 | | | = | $1,820 | | |
| **C** Person C | $62,000 | | | x | 0.030 | | | = | $1,860 | | |
| **D** Person D | | | | x | | | | = | | | |
| **E** Person E | | | | x | | | | = | | | |
| **F** Person F | | | | x | | | | = | | | |
| **G** Person G | $26,420 | | | x | 0.500 | | | = | $13,210 | | |
| **H** Person H | | | | x | | | | = | | | |

Total Existing Staff Salary Component **Box A** **$21,440**

| **Associated Costs** | | | | | |
|---|---|---|---|---|---|
| ACC Levy | 1.71% | x | $21,440 | = | $367 |
| Superannuation | 4.5% | x | $21,440 | = | $965 |

| **New Staff** | | | | |
|---|---|---|---|---|
| **I** | | x | | = |
| **J** | | x | | = |
| **K** | | x | | = |
| **L** | | x | | = |
| **M** | | x | | = |
| **N** | | x | | = |
| **O** | | x | | = |
| **P** | | x | | = |

Total New Staff Salary Component **Box B**

| **Associated Costs** | | | | |
|---|---|---|---|---|
| ACC Levy | 1.71% | x | = | |
| Superannuation | 4.5% | x | = | |
| Recruitment/Advertising & Relocation Costs | 2.2% | x | = | |

| | | |
|---|---|---|
| **Salary Component for Existing and New Staff** | **Box C** | **$21,440** |
| **Total Associated Personnel Costs** | **Box D** | **$1,331** |
| **TOTAL PERSONNEL COSTS** | **Box E** | **$22,771** |

## 2. General Operating Costs

| | | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|
| Travel: | Domestic | = | | | |
| | International | = | | | |
| Conference Fees | | = | | | |
| Accommodation | | = | | | |
| Fieldwork Costs: | Accommodation | = | | | |
| | Per Diem | = | | | |
| Materials and Consumables | | = | $8,107 | | |
| Computing Costs, S'ware Development | | = | $500 | | |
| Report Preparation Costs | | = | | | |
| Printing, Photocopying and Photographic | | = | | | |
| Library Costs | | = | | | |
| Telephone, Tolls, Facsimile | | = | | | |
| Legal Costs | | = | | | |
| Health and Safety costs | | = | | | |
| Equipment (individual items less than $5000) | | = | | | |
| External Consultants | | = | | | |
| Other Operating Costs | | = | | | |

**TOTAL GENERAL OPERATING COSTS** **Box F** **$8,607**

## 3. Premises Costs

| | *Proportion* | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|
| Lab Intensive Research | 0.50 | 0.057 x $21,440 | = | $611 | | |
| Field-work Research | | 0.040 x $21,440 | = | | | |

**TOTAL PREMISES COSTS** **Box G** **$611**

## 4. Equipment Depreciation

| | *Equipment Cost* | | *Fraction of Time Used* | | *Year 1* | *Year 2* | *Year 3* | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Year 1* | *Year 2* | *Year 3* | **Year 1** | **Year 2** | **Year 3** |
| Computers | $2,600 | x | 0.33 | x | 0.200 | | | $172 | | |
| | | x | 0.33 | x | | | | | | |
| | | x | 0.33 | x | | | | | | |
| Computer Driven Equipment | | x | 0.20 | x | | | | | | |
| | | x | 0.20 | x | | | | | | |
| | | x | 0.20 | x | | | | | | |
| Other Equipment | | x | 0.10 | x | | | | | | |
| | | x | 0.10 | x | | | | | | |
| | | x | 0.10 | x | | | | | | |

| | *Cost per hour* | | *No of hours used* | | |
|---|---|---|---|---|---|
| | | | *Year 1* | *Year 2* | *Year 3* |
| Equipment Rental | | x | | | |
| Equipment Maintenance | | = | | | |

**TOTAL EQUIPMENT DEPRECIATION & RENTAL** **Box H** **$172**

## 5. Overheads

| | | *Staff Costs* | | **Year 1** | **Year 2** | **Year 3** |
|---|---|---|---|---|---|---|
| 1.00 | x | $21,440 | = | $21,440 | | |

**TOTAL OVERHEADS** **Box I** **$21,440**

## 6. Extraordinary Costs

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| Research Unit/Farm Costs | = | $6,765 | | |
| Patenting Costs | = | | | |
| Computer Software Acquisition | = | | | |
| Access to Special Proprietary Databases | = | | | |
| Access to Special Equip & Services | = | | | |
| Casual Assistance for Extensive Fieldwork | = | | | |
| "Koha" for Marae Visits etc | = | | | |
| Staff Training Costs | = | | | |
| Laboratory remodelling | = | | | |
| Other Extraordinary Costs | = | | | |
| **TOTAL EXTRAORDINARY EXPENSES** | **Box J** | **$6,765** | | |

## SUMMARY FOR OBJECTIVE

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| Personnel Costs | | $22,771 | | |
| General Operating Costs | | $8,607 | | |
| Premises Costs | | $611 | | |
| Equipment Depreciation & Rental | | $172 | | |
| Overheads | | $21,440 | | |
| Extraordinary Expenses | | $6,765 | | |
| **Sub Total** | **Box K** | **$60,366** | | |
| GST 12.5% x $60,366 | = | $7,546 | | |
| **TOTAL COST COST OF OBJECTIVE** | | **$67,912** | | |

# PGSF Spreadsheet

## 1. Personnel

| | Salary pa ($) Year 1 | Year 2 | Year 3 | | Fraction of time spent on objective Year 1 | Year 2 | Year 3 | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Existing Staff** | | | | | | | | | | | |
| **A** Person A | | | | x | | | | = | | | |
| **B** Person B | | | | x | | | | = | | | |
| **C** Person C | | | | x | | | | = | | | |
| **D** Person D | $73,000 | | | x | 0.030 | | | = | $2,190 | | |
| **E** Person E | | | | x | | | | = | | | |
| **F** Person F | | | | x | | | | = | | | |
| **G** Person G | $26,420 | | | x | 0.500 | | | = | $13,210 | | |
| **H** Person H | | | | x | | | | = | | | |
| | Total Existing Staff Salary Component | | | | | | **Box A** | | **$15,400** | | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | | 1.71% | | x | $15,400 | | | = | $263 | | |
| Superannuation | | 4.5% | | x | $15,400 | | | = | $693 | | |
| **New Staff** | | | | | | | | | | | |
| **I** | | | | x | | | | = | | | |
| **J** | | | | x | | | | = | | | |
| **K** | | | | x | | | | = | | | |
| **L** | | | | x | | | | = | | | |
| **M** | | | | x | | | | = | | | |
| **N** | | | | x | | | | = | | | |
| **O** | | | | x | | | | = | | | |
| **P** | | | | x | | | | = | | | |
| | Total New Staff Salary Component | | | | | | **Box B** | | | | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | | 1.71% | | x | | | | = | | | |
| Superannuation | | 4.5% | | x | | | | = | | | |
| Recruitment/Advertising & Relocation Costs | | 2.2% | | x | | | | = | | | |

| | | |
|---|---|---|
| **Salary Component for Existing and New Staff** | **Box C** | **$15,400** |
| **Total Associated Personnel Costs** | **Box D** | **$956** |
| **TOTAL PERSONNEL COSTS** | **Box E** | **$16,356** |

## 2. General Operating Costs

| | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|
| Travel: | Domestic | = | | | |
| | International | = | | | |
| Conference Fees | | = | | | |
| Accommodation | | = | | | |
| Fieldwork Costs: | Accommodation | = | | | |
| | Per Diem | = | | | |
| Materials and Consumables | | = | $9,613 | | |
| Computing Costs, S'ware Development | | = | | | |
| Report Preparation Costs | | = | | | |
| Printing, Photocopying and Photographic | | = | | | |
| Library Costs | | = | | | |
| Telephone, Tolls, Facsimile | | = | | | |
| Legal Costs | | = | | | |
| Health and Safety costs | | = | | | |
| Equipment (individual items less than $5000) | | = | | | |
| External Consultants | | = | | | |
| Other Operating Costs | | = | | | |

**TOTAL GENERAL OPERATING COSTS** **Box F** **$9,613**

## 3. Premises Costs

| | *Proportion* | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|
| Lab Intensive Research | 0.25 | 0.057 x $15,400 | = | $219 | | |
| Field-work Research | | 0.040 x $15,400 | = | | | |

**TOTAL PREMISES COSTS** **Box G** **$219**

## 4. Equipment Depreciation

| | Equipment Cost | | Fraction of Time Used Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|
| Computers | $2,600 | x 0.33 x | 0.130 | | | $112 | | |
| | | x 0.33 x | | | | | | |
| | | x 0.33 x | | | | | | |
| Computer Driven Equipment | | x 0.20 x | | | | | | |
| | | x 0.20 x | | | | | | |
| | | x 0.20 x | | | | | | |
| Other Equipment | | x 0.10 x | | | | | | |
| | | x 0.10 x | | | | | | |
| | | x 0.10 x | | | | | | |
| | *Cost per hour* | | *No of hours used* Year 1 | Year 2 | Year 3 | | | |
| Equipment Rental | | x | | | | | | |
| Equipment Maintenance | | = | | | | | | |

**TOTAL EQUIPMENT DEPRECIATION & RENTAL** **Box H** **$112**

## 5. Overheads

| | | Staff Costs | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|
| | 1.00 x | $15,400 | = | $15,400 | | |

**TOTAL OVERHEADS** **Box I** **$15,400**

## 6. Extraordinary Costs

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| Research Unit/Farm Costs | = | $2,850 | | |
| Patenting Costs | = | | | |
| Computer Software Acquisition | = | | | |
| Access to Special Proprietary Databases | = | | | |
| Access to Special Equip & Services | = | | | |
| Casual Assistance for Extensive Fieldwork | = | | | |
| "Koha" for Marae Visits etc | = | | | |
| Staff Training Costs | = | | | |
| Laboratory remodelling | = | | | |
| Other Extraordinary Costs | = | | | |

**TOTAL EXTRAORDINARY EXPENSES** **Box J** **$2,850**

## SUMMARY FOR OBJECTIVE

| | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| Personnel Costs | $16,356 | | |
| General Operating Costs | $9,613 | | |
| Premises Costs | $219 | | |
| Equipment Depreciation & Rental | $112 | | |
| Overheads | $15,400 | | |
| Extraordinary Expenses | $2,850 | | |

**Sub Total** **Box K** **$44,550**

GST 12.5% x $44,550 = $5,569

**TOTAL COST COST OF OBJECTIVE** **$50,119**

# PGSF Spreadsheet

## 1. Personnel

| | Salary pa ($) Year 1 | Year 2 | Year 3 | | Fraction of time spent on objective Year 1 | Year 2 | Year 3 | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Existing Staff** | | | | | | | | | | | |
| **A** Person A | $91,000 | | | x | 0.030 | | | = | $2,730 | | |
| **B** Person B | | | | x | | | | = | | | |
| **C** Person C | $62,000 | | | x | 0.030 | | | = | $1,860 | | |
| **D** Person D | $73,000 | | | x | 0.030 | | | = | $2,190 | | |
| **E** Person E | $26,420 | | | x | 0.050 | | | = | $1,321 | | |
| **F** Person F | | | | x | | | | = | | | |
| **G** Person G | | | | x | | | | = | | | |
| **H** Person H | | | | x | | | | = | | | |

Total Existing Staff Salary Component — **Box A** — **$8,101**

| **Associated Costs** | | | | | |
|---|---|---|---|---|---|
| ACC Levy | 1.71% | x | $8,101 | = | $139 |
| Superannuation | 4.5% | x | $8,101 | = | $365 |

| **New Staff** | | | |
|---|---|---|---|
| **I** | x | = | |
| **J** | x | = | |
| **K** | x | = | |
| **L** | x | = | |
| **M** | x | = | |
| **N** | x | = | |
| **O** | x | = | |
| **P** | x | = | |

Total New Staff Salary Component — **Box B** —

| **Associated Costs** | | | |
|---|---|---|---|
| ACC Levy | 1.71% | x | = |
| Superannuation | 4.5% | x | = |
| Recruitment/Advertising & Relocation Costs | 2.2% | x | = |

| | | |
|---|---|---|
| **Salary Component for Existing and New Staff** | **Box C** | **$8,101** |
| **Total Associated Personnel Costs** | **Box D** | **$503** |
| **TOTAL PERSONNEL COSTS** | **Box E** | **$8,604** |

## 2. General Operating Costs

| | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|
| Travel: | Domestic | = | | | |
| | International | = | | | |
| Conference Fees | | = | | | |
| Accommodation | | = | | | |
| Fieldwork Costs: | Accommodation | = | | | |
| | Per Diem | = | | | |
| Materials and Consumables | | = | $3,291 | | |
| Computing Costs, S'ware Development | | = | $350 | | |
| Report Preparation Costs | | = | | | |
| Printing, Photocopying and Photographic | | = | | | |
| Library Costs | | = | | | |
| Telephone, Tolls, Facsimile | | = | | | |
| Legal Costs | | = | | | |
| Health and Safety costs | | = | | | |
| Equipment (individual items less than $5000) | | = | | | |
| External Consultants | | = | | | |
| Other Operating Costs | | = | | | |
| **TOTAL GENERAL OPERATING COSTS** | **Box F** | | **$3,641** | | |

## 3. Premises Costs

| | *Proportion* | | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|---|
| Lab Intensive Research | 0.25 | 0.057 x | $8,101 | = | $115 | | |
| Field-work Research | | 0.040 x | $8,101 | = | | | |
| **TOTAL PREMISES COSTS** | | | **Box G** | | **$115** | | |

## 4. Equipment Depreciation

| | Equipment Cost | | | | Fraction of Time Used Year 1 | Year 2 | Year 3 | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|---|---|
| Computers | $2,600 | x | 0.33 | x | 0.140 | | | $120 | | |
| | | x | 0.33 | x | | | | | | |
| | | x | 0.33 | x | | | | | | |
| Computer Driven Equipment | | x | 0.20 | x | | | | | | |
| | | x | 0.20 | x | | | | | | |
| | | x | 0.20 | x | | | | | | |
| Other Equipment | | x | 0.10 | x | | | | | | |
| | | x | 0.10 | x | | | | | | |
| | | x | 0.10 | x | | | | | | |

| | Cost per hour | | No of hours used Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|
| Equipment Rental | | x | | | |
| Equipment Maintenance | | = | | | |

**TOTAL EQUIPMENT DEPRECIATION & RENTAL** **Box H** **$120**

## 5. Overheads

| | | Staff Costs | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|
| 1.00 | x | $8,101 | = | $8,101 | | |

**TOTAL OVERHEADS** **Box I** **$8,101**

## 6. Extraordinary Costs

| | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|
| Research Unit/Farm Costs | = | $1,400 | | |
| Patenting Costs | = | | | |
| Computer Software Acquisition | = | | | |
| Access to Special Proprietary Databases | = | | | |
| Access to Special Equip & Services | = | | | |
| Casual Assistance for Extensive Fieldwork | = | | | |
| "Koha" for Marae Visits etc | = | | | |
| Staff Training Costs | = | | | |
| Laboratory remodelling | = | | | |
| Other Extraordinary Costs | = | | | |
| **TOTAL EXTRAORDINARY EXPENSES** | **Box J** | **$1,400** | | |

## SUMMARY FOR OBJECTIVE

| | | | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|---|
| | Personnel Costs | | | | $8,604 | | |
| | General Operating Costs | | | | $3,641 | | |
| | Premises Costs | | | | $115 | | |
| | Equipment Depreciation & Rental | | | | $120 | | |
| | Overheads | | | | $8,101 | | |
| | Extraordinary Expenses | | | | $1,400 | | |
| **Sub Total** | | | | **Box K** | **$21,982** | | |
| GST | 12.5% | x | $21,982 | = | $2,748 | | |
| **TOTAL COST COST OF OBJECTIVE** | | | | | **$24,729** | | |

## 1. Personnel

| | Salary pa ($) Year 1 | Salary pa ($) Year 2 | Salary pa ($) Year 3 | | Fraction of time spent on objective Year 1 | Fraction of time spent on objective Year 2 | Fraction of time spent on objective Year 3 | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Existing Staff** | | | | | | | | | | | |
| **A** Person A | $91,000 | $91,000 | | x | 0.040 | 0.040 | | = | $3,640 | $3,640 | |
| **B** Person B | $91,000 | $91,000 | | x | 0.040 | 0.040 | | = | $3,640 | $3,640 | |
| **C** Person C | $62,000 | $62,000 | | x | 0.060 | 0.060 | | = | $3,720 | $3,720 | |
| **D** Person D | | | | x | | | | = | | | |
| **E** Person E | $26,420 | $26,420 | | x | 0.050 | 0.050 | | = | $1,321 | $1,321 | |
| **F** Person F | | | | x | | | | = | | | |
| **G** Person G | | | | x | | | | = | | | |
| **H** Person H | $26,420 | $26,420 | | x | 0.250 | 0.250 | | = | $6,605 | $6,605 | |
| | Total Existing Staff Salary Component | | | | | | **Box A** | | **$18,926** | **$18,926** | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | | 1.7% | | x | $18,926 | $18,926 | | = | $324 | $324 | |
| Superannuation | | 4.5% | | x | $18,926 | $18,926 | | = | $852 | $852 | |
| **New Staff** | | | | | | | | | | | |
| **I** | | | | x | | | | = | | | |
| **J** | | | | x | | | | = | | | |
| **K** | | | | x | | | | = | | | |
| **L** | | | | x | | | | = | | | |
| **M** | | | | x | | | | = | | | |
| **N** | | | | x | | | | = | | | |
| **O** | | | | x | | | | = | | | |
| **P** | | | | x | | | | = | | | |
| | Total New Staff Salary Component | | | | | | **Box B** | | | | |
| **Associated Costs** | | | | | | | | | | | |
| ACC Levy | | 1.7% | | x | | | | = | | | |
| Superannuation | | 4.5% | | x | | | | = | | | |
| Recruitment/Advertising & Relocation Costs | | 2.2% | | x | | | | = | | | |
| **Salary Component for Existing and New Staff** | | | | | | | **Box C** | | **$18,926** | **$18,926** | |
| **Total Associated Personnel Costs** | | | | | | | **Box D** | | **$1,175** | **$1,175** | |
| **TOTAL PERSONNEL COSTS** | | | | | | | **Box E** | | **$20,101** | **$20,101** | |

## 2. General Operating Costs

| | | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|
| Travel: | Domestic | = | $100 | $100 | |
| | International | = | | | |
| Conference Fees | | = | | | |
| Accommodation | | = | | | |
| Fieldwork Costs: | Accommodation | = | | | |
| | Per Diem | = | | | |
| Materials and Consumables | | = | $12,848 | $12,848 | |
| Computing Costs, S'ware Development | | = | $500 | $500 | |
| Report Preparation Costs | | = | | | |
| Printing, Photocopying and Photographic | | = | | | |
| Library Costs | | = | | | |
| Telephone, Tolls, Facsimile | | = | | | |
| Legal Costs | | = | | | |
| Health and Safety costs | | = | | | |
| Equipment (individual items less than $5000) | | = | | | |
| External Consultants | | = | | | |
| Other Operating Costs | | = | | | |
| **TOTAL GENERAL OPERATING COSTS** | **Box F** | | **$13,448** | **$13,448** | |

## 3. Premises Costs

| | *Proportion* | | | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|---|---|
| Lab Intensive Research | 0.50 | 0.057 x | $18,926 | $18,926 | = | $539 | $539 | |
| Field-work Research | | 0.040 x | $18,926 | $18,926 | = | | | |
| **TOTAL PREMISES COSTS** | | | | **Box G** | | **$539** | **$539** | |

## 4. Equipment Depreciation

| | *Equipment Cost* | | | | *Fraction of Time Used* | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Year 1* | *Year 2* | *Year 3* | | | |
| Computers | $2,600 | x | 0.33 | x | 0.290 | 0.290 | | $249 | $249 | |
| | | x | 0.33 | x | | | | | | |
| | | x | 0.33 | x | | | | | | |
| Computer Driven Equipment | | x | 0.20 | x | | | | | | |
| | | x | 0.20 | x | | | | | | |
| | | x | 0.20 | x | | | | | | |
| Other Equipment | | x | 0.10 | x | | | | | | |
| | | x | 0.10 | x | | | | | | |
| | | x | 0.10 | x | | | | | | |
| | *Cost per hour* | | | | *No of hours used* | | | | | |
| | | | | | *Year 1* | *Year 2* | *Year 3* | | | |
| Equipment Rental | | | | x | | | | | | |
| Equipment Maintenance | | | | = | | | | | | |
| **TOTAL EQUIPMENT DEPRECIATION & RENTAL** | | | | | | | **Box H** | **$249** | **$249** | |

## 5. Overheads

| | | | *Staff Costs* | | | *Year 1* | *Year 2* | *Year 3* |
|---|---|---|---|---|---|---|---|---|
| | 1.00 | x | $18,926 | $18,926 | = | $18,926 | $18,926 | |
| **TOTAL OVERHEADS** | | | | | **Box I** | **$18,926** | **$18,926** | |

## 6. Extraordinary Costs

| | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|
| Research Unit/Farm Costs | = | $1,350 | $1,350 | |
| Patenting Costs | = | | | |
| Computer Software Acquisition | = | | | |
| Access to Special Proprietary Databases | = | | | |
| Access to Special Equip & Services | = | | | |
| Casual Assistance for Extensive Fieldwork | = | | | |
| "Koha" for Marae Visits etc | = | | | |
| Staff Training Costs | = | | | |
| Laboratory remodelling | = | | | |
| Other Extraordinary Costs | = | | | |
| **TOTAL EXTRAORDINARY EXPENSES** | **Box J** | **$1,350** | **$1,350** | |

## SUMMARY FOR OBJECTIVE

| | | | | | Year 1 | Year 2 | Year 3 |
|---|---|---|---|---|---|---|---|
| Personnel Costs | | | | | $20,101 | $20,101 | |
| General Operating Costs | | | | | $13,448 | $13,448 | |
| Premises Costs | | | | | $539 | $539 | |
| Equipment Depreciation & Rental | | | | | $249 | $249 | |
| Overheads | | | | | $18,926 | $18,926 | |
| Extraordinary Expenses | | | | | $1,350 | $1,350 | |
| **Sub Total** | | | | **Box K** | **$54,614** | **$54,614** | |
| GST | 12.5% | x | $54,614 | $54,614 = | $6,827 | $6,827 | |
| **TOTAL COST COST OF OBJECTIVE** | | | | | **$61,440** | **$61,440** | |

# APPENDIX V: COPIES OF THE QUESTIONNAIRES

Two mail questionnaires were sent out during the study. These were a survey of shearing contractors and a survey of Wool Production Officers. Copies of the two questionnaires are included in this Appendix.

# WINTER COMB SHEARING

1. Have you or your staff shorn any sheep using a winter comb? **Yes / No** (Please circle one)

IF YES PLEASE GO TO QUESTION 2, IF NO PLEASE GO TO QUESTION 10.

2. When did you begin shearing using the winter comb? **19...........**

3. Please provide estimates of sheep shorn in total and the percentages shorn with the different types of combs in 1995/96, 1992/93, 1985/86 and an estimate for the season beginning July 2000. **Number shorn only needs to be to the nearest thousand. Only complete years in which you were contracting.**

**Note: For this study lambs become hoggets at the end of April and hoggets become ewes at the end of October.**

| | Total number of sheep shorn | Percentage shorn with winter combs | Percentage shorn with a Big 10 or Sunbeam 9 | Percentage shorn with a Gould Lifter | Percentage shorn with blades |
|---|---|---|---|---|---|
| 1995/96 - Ewes | | | | | |
| - Hoggets | | | | | |
| - Lambs | | | | | |
| | | | | | |
| 1992/93 - Ewes | | | | | |
| - Hoggets | | | | | |
| - Lambs | | | | | |
| | | | | | |
| 1985/86 - Ewes | | | | | |
| - Hoggets | | | | | |
| - Lambs | | | | | |
| | | | | | |
| 2000/01 - Ewes | | | | | |
| - Hoggets | | | | | |
| - Lambs | | | | | |

4. Please indicate the main months of shearing with a winter comb in 1992/93, 1995/96 and an estimate for the season beginning July 2000 (for example, May to September).

| Timing | Ewes | Hoggets | Lambs |
|---|---|---|---|
| 1992/93 | | | |
| 1995/96 | | | |
| 2000/01 | | | |

5(a). What proportion of your clients ask for sheep to be shorn between May and September? ......................%

(b). What proportion of these clients ask for their sheep to be shorn with a winter comb? ......................%

6. What proportion of the sheep now shorn with a winter comb were previously shorn with

(a) a conventional comb? ........... %
(b) blades? ........... %
(c) other type of comb? (e.g. Big 10) ........... %
Please specify comb type ..............................................

7(a). Has the number of sheep shorn in the winter-early spring (May to September) increased in the past five years? **Yes / No** (Please circle one)

IF NO, PLEASE GO TO QUESTION 8.

(b). Compared to the 1992/93 season, by how much has the proportion of sheep shorn in winter-early spring (May to September) increased? ..............%

8(a). Do you encourage your clients to winter shear? **Yes / No** (Please circle one)

(b). IF YES, please describe any problems you have experienced in encouraging farmers to use the winter comb?
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9. Please describe any problems you have experienced in encouraging shearers to use the winter comb?
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10. Please circle the option which best describes your views on the following statements.

(a) Winter combs reduce sheep losses after shearing.

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

(b) Using the winter comb enables farmers to save feed during the first 3 weeks after shearing.

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

(c) Winter combs are easier to shear with than conventional combs.

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

(d) Farmers know the difference between types of combs for winter shearing. (e.g. Big10, Sunbeam 9, cover comb, high country comb)

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

(e) Big 10 and Sunbeam 9 combs are as effective as the Sunbeam cover comb, the Heiniger high country comb and the Chinese John Hand comb for winter shearing.

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

(f) Shearers should be paid the same for using winter combs as conventional combs.

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

(g) Information on the effect of the winter comb on sheep production and losses is easy to obtain.

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

(h) The winter comb is more widely used if the winter-spring is colder and/or wetter than normal.

**Not Sure** **Strongly Disagree** **Disagree** **Agree** **Strongly Agree**

11(a). Are there other opportunities to use the winter comb for shearing in your local area? **Yes / No** (Please circle one)

(b). IF YES, please describe what these opportunities are? (i.e. for ewes, hoggets and lambs; reasons for using a cover comb.)

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12(a). Are there factors which prevent more widespread use of winter combs in your local area? **Yes / No** (Please circle one)

(b). IF YES, please list these factors and briefly describe why they are limiting winter comb use, and where appropriate, indicate how these limitations may be overcome.

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**If you would like to add additional comments, please do so on the reverse side of this page or attach a separate sheet.**

**Can we contact you for any clarification or additional information we need?**
**Yes / No** (Please circle one)

IF YES, PLEASE PROVIDE CONTACT INFORMATION.

**Name** ........................................................

How would you like to be contacted? (Please circle the appropriate option(s) and provide relevant details).

(a) by mail
(b) by telephone : (Please indicate the most convenient time to ring)
.........................................................................................
(c) by fax : (Please provide your fax number) ............................................

**Thank you for participating in this survey.**

# COVER COMB EXTENSION ACTIVITIES

**Region ..................................................**

**Cost of Cover Comb Extension Activities (since late 1992)**
Please answer either questions 1 to 5, or question 6.

EITHER

1. How many field days did you hold since late 1992 at which the cover comb was discussed? **........ fieldays**

2. What amount of your time at fieldays, on average, was spent discussing the cover comb? **........ hours**

3. What was the average total cost, (excluding your time), of the field days? **$ .............**

4. If not included in field day costs, what other costs did you incur in preparing information on the cover comb technology for field days? (e.g. time involved, phone calls, equipment, etc)
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5. What other time did you devote to extension activities related to the cover comb? (e.g. preparation of articles, one on one visits etc) **Please provide an estimate of the total time involved and briefly describe what the activities were**.
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OR

6. What proportion of the total amount of your time did you spend annually on cover comb extension? **Please describe briefly what the activities were.**
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## Uptake of Cover Comb Technology in your Local Region

7. Please complete the table below for your local region. **(Use your best estimate to complete the table.)**

**Note: For this study lambs become hoggets at the end of April and hoggets become ewes at the end of October. You may wish to check numbers with some contractors.**

| 1995/96 season | Ewes | Hoggets | Lambs |
|---|---|---|---|
| **Number of sheep shorn in region** | | | |
| **Number shorn by cover comb** | | | |
| **Time of shearing with cover comb** | | | |

8. Please provide general comments on the uptake of the cover comb in your region. (i.e. when it was first used, adoption rate, numbers shorn, classes of stock and when sheep are shorn with a cover comb.)

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9. What further opportunities are there for the use of the cover comb technology in your region? (i.e. for ewes, hoggets, lambs; reasons for using a cover comb.)

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10. What factors constrain the further adoption of cover comb technology in your local area? **Please list these factors and briefly describe why they are a constraint, and where appropriate, indicate how these may be overcome.**

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11. Please make an estimate of reduction in sheep losses following shearing with a cover comb?

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**If you would like to add additional comments, please do so on the reverse side of this page or attach a separate sheet.**

**Thank you for participating in this survey.**

# APPENDIX VI: NUMBER OF EWE AND HOGGET SHEARINGS WITH A COVER COMB BASED ON CONTRACTORS DATA

**Number of ewe and hogget shearings with a cover comb in 1992/93 and 1995/96. (Overall numbers shorn in the North and South Island are based on sample percentage shorn. Number in each Island and number cover comb (CC) -shorn refers to shearings rather than sheep. Total numbers in the North and South Island are in thousands.)**

| | Ewes | | Hoggets | | Ewes and Hoggets | |
|---|---|---|---|---|---|---|
| | 1992/93 | 1995/96 | 1992/93 | 1995/96 | 1992/93 | 1995/96 |
| **North Island** | | | | | | |
| No. Contractors | 5 | 5 | 5 | 5 | 6 | 7 |
| No. Shorn | 1391404 | 1259712 | 453693 | 441358 | 2605097 | 2968070 |
| No. C C Shorn | 225474 | 211434 | 48700 | 73539 | 287475 | 476373 |
| % C C Shorn | 16.20 | 16.78 | 10.73 | 16.66 | 11.04 | 16.05 |
| | | | | | | |
| No. in North Is. | 26789 | 25783 | 6435 | 5886 | 33224 | 31669 |
| No. cover comb | 4340 | 4326 | 689 | 981 | 3666 | 5083 |
| | | | | | | |
| **South Island** | | | | | | |
| No. Contractors | 2 | 3 | 2 | 3 | 3 | 5 |
| No. Shorn | 367000 | 628335 | 113000 | 151205 | 725000 | 1420540 |
| No. C C Shorn | 106500 | 173644 | 3300 | 8016 | 330300 | 618560 |
| % C C Shorn | 29.02 | 27.64[1] | 2.92 | 5.30[2] | 45.56 | 43.54[3] |
| | | | | | | |
| No. in South Is. | 21748 | 20873 | 5552 | 5986 | 27300 | 26859 |
| No. cover comb | 6307 | 5769 | 161 | 317 | 12438 | 11694 |
| | | | | | | |
| % C C in NZ | 21.9 | 21.6[4] | 7.1 | 10.9[5] | 26.6 | 28.7[6] |
| No. shorn | 48537 | 46656 | 11987 | 11872 | 60524 | 58528 |
| No. C C shorn | 10647 | 10095 | 850 | 1298 | 16104 | 16777 |

[1]33.23% including ewes shorn with a Gould lifter.
[2]5.8% including hoggets shorn with a Gould lifter.
[3]46.07% including ewes and hoggets shorn with a Gould lifter.
[4]24.1% including ewes shorn with a Gould lifter.
[5]11.2% including hoggets shorn with a Gould lifter.
[6]29.8% including ewes and hoggets shorn with a Gould lifter.

# APPENDIX VII: OFFICIAL ESTIMATES OF THE REGIONAL POPULATIONS OF SHEEP AND THE PERCENTAGE OF EWES, HOGGETS AND LAMBS SHORN WITH A COVER COMB

**Regional populations of sheep and estimated percentage of ewes and hoggets shorn with a cover comb based on official numbers. (Numbers are in thousands).**

| Region | Total number shorn ('000) | % Cover comb shorn | No. cover comb shorn ('000) |
|---|---|---|---|
| **Northland/Auckland/Waikato/Bay of Plenty** | | | |
| Ewes | 4469 | 0.5 | 22 |
| Hoggets | 2253 | 5.0 | 113 |
| **Hawkes Bay/Poverty Bay** | | | |
| Ewes | 4320 | 21.4 | 907 |
| Hoggets | 2178 | 38.9 | 849 |
| **Taranaki/Manawatu/Wanganui** | | | |
| Ewes | 3277 | 5.6 | 184 |
| Hoggets | 1652 | 20.0 | 330 |
| **Wairarapa/Tararua** | | | |
| Ewes | 2830 | 35.0 | 991 |
| Hoggets | 1427 | 85.0 | 1213 |
| **Otago** | | | |
| Ewes | 5541 | 47.5 | 2632 |
| Hoggets | 2245 | 33.3 | 748 |

NZMWBES figures are used to calculate number of sheep in the regions. NZMWBES regions differ from those of Wools of New Zealand, so figures are approximations only.

# APPENDIX VIII: SPREADSHEET TEMPLATES USED IN THE CALCULATION OF BENEFITS, SHEEP SHORN AND RESEARCH RETURNS

The main spreadsheets templates used in the model are outlined in this Appendix. This is in four sections:

## APPENDIX VIII.1: Description of the Spreadsheets

There were a number of worksheets in the spreadsheet: the main worksheets were the "Year" and the "IRR" worksheets. Spreadsheet information entered by the user is highlighted in blue and calculated fields are shown in black. Parameters are entered in the red cells and can be changed if more accurate information is known, or a sensitivity analysis needs to be carried out.

The Year worksheet calculates the numbers shorn with a cover comb, both with and without the research, for a specific year. The Year worksheet template can be copied and renamed, to generate a worksheet for each year that this information is required. The year the calculations are being done for and the opening numbers (on a national, Island or regional basis) are entered at the top of the worksheet. Numbers shorn are calculated from the opening numbers.

The parameters used in the Year worksheet (e.g. different classes of sheep and the numbers shorn, as a proportion of opening numbers are stored in the Param worksheet. Most of these parameters were calculated from New Zealand Meat and Wool Board Economic Service (NZMWBES) data.

The IRR worksheet calculates the return to investment as an internal rate of return (IRR), and a net present value (NPV) and cost-benefit ratio (CBR) for a specified discount rate. Numbers shorn with a cover comb for key years are copied from the Year worksheets, and the values for the intervening years are extrapolated from the differences. One year per column has been allowed. Numbers are entered for ewes, ewe hoggets, other sheep, and lambs. For the cover comb study the total ewe figure (group 1) has been entered in the Ewe - PLS row. The ewe figures in this sheet are able to be separated out to allow for research that may impact on different shearing policies (full wool policies, both pre-lamb and conventionally shorn, eight monthly shearing policies and second shear policies). Currently information on ewes shorn with different shearing policies is not readily available, however these data can be included in the Year worksheet at a later date as information becomes available.

There are 3 IRR worksheets: the IRR worksheet calculates the investment returns from research and extension for this study; the IRRD worksheet calculates the investment returns from research, development and extension for this study; and the IRRS worksheet can be used for sensitivity analysis. The outputs (IRR, NPV and CBR) for the three IRR worksheets are stored in the Output, Outputd and outputs worksheets, respectively. The discount rate is also entered in these output sheets.

Two worksheets are used in the calculation of benefits. These are Benefit1 and Benefit2. Benefit2 calculates the net benefit for ewes, ewe hoggets and lambs from a reduction in sheep losses due to shearing with a cover comb rather than a conventional comb. It also allows for a reduction in feed intakes to be included. Prices, production parameters and the percentage reduction in losses can be changed for sensitivity analysis. Benefit1 estimates the percentage of ewes nationally which changed to being cover comb shorn because of policy changes or a change from blade shearing from 1990/91 to 1995/96. The net/benefit per ewe associated with a change to cover comb shearing is then calculated based on the benefits associated with a policy change, a change to cover comb shearing from blade shearing and a reduction in losses, and the proportion of ewes associated with each change.

**APPENDIX VIII.2: Spreadsheet template used to calculate benefit per ewe cover comb-shorn.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| COVER COMB SHEARING | | | | | | | |
| Year | | 90/91 | 91/92 | 92/93 | 93/94 | 94/95 | 95/96 |
| No. sheep open (000) | | 57852 | 55162 | 52569 | 50298 | 49466 | 48000 |
| No. sheep shorn (000) | | 52258 | 49828 | 47486 | 45434 | 44683 | 43358 |
| No. ewes shorn (000) | | 39131 | 37311 | 35558 | 34021 | 33459 | 32467 |
| | | | | | | | |
| % diff ewes CC shorn | | 10% | 10% | 15% | 15% | 15% | 15% |
| No. ewes CC shorn (000) | | 3913 | 3731 | 5334 | 5103 | 5019 | 4870 |
| | | | | | | | |
| BLADE SHEARING | | | | | | | |
| | | | | | | | |
| %blade shorn/sheep shorn | | 3.268% | 2.861% | 2.445% | 3.157% | 4.121% | 3.170% |
| Sheep blade shorn (000) | | 1708 | 1425 | 1161 | 1434 | 1841 | 1374 |
| Ewes blade shorn (000) | | 1279 | 1067 | 869 | 1074 | 1379 | 1029 |
| | | | | | | | |
| % blades changed to CC this yr | | 0% | 17% | 15% | -17% | -22% | 34% |
| % blades changed to CC (cum) | | 0% | 17% | 32% | 15% | -7% | 15% |
| No. ewes blade to CC (000) | | 0 | 181 | 278 | 161 | -97 | 154 |
| | | | | | | | |
| % B to CC | | 0.0% | 4.9% | 5.2% | 3.2% | -1.9% | 3.2% |
| | | | | | | | |
| | | | | | | | |
| POLICY CHANGES | | | | | | | |
| | | | | | | | |
| % total ewes change pol this yr | | 0.20% | 0.24% | 0.56% | 0.00% | 0.00% | 0.00% |
| % total ewes changing policies | | 0.20% | 0.44% | 1.00% | 1.00% | 1.00% | 1.00% |
| No. ewes change pol this yr (000) | | 78 | 90 | 199 | 0 | 0 | 0 |
| No. ewes change policies (000) | | 78 | 164 | 356 | 340 | 335 | 325 |
| Difference (year 2+) | | 0 | 75 | 156 | 340 | 335 | 325 |
| | | | | | | | |
| % policy change to CC | | 2.0% | 4.4% | 6.7% | 6.7% | 6.7% | 6.7% |
| % policy change to CC this year | | 2.0% | 2.4% | 3.7% | 0.0% | 0.0% | 0.0% |
| % policy change to CC (year 2+) | | 0.0% | 2.0% | 2.9% | 6.7% | 6.7% | 6.7% |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| NET BENEFITS ASSOCIATED WITH COVER COMB SHEARING | | | | | | | |
| (EXTRA COST PER SHEEP FOR COVER COMB SHEARING IS EXCLUDED HERE) | | | | | | | |
| | | | | | | | |
| BENEFITS ($/EWE) | | | | | | | |
| | NET | % EWES | TOTAL | | | | |
| | BENEFIT | | BENEFIT | | | | |
| POLICY CHG Y2+ | 1.000 | 5.0% | 0.050 | | | | |
| POLICY CHG Y1 | 0.000 | 0.0% | 0.000 | | | | |
| BLADES TO CC | 0.730 | 3.0% | 0.022 | | | | |
| PLS | 0.516 | 92.0% | 0.475 | | | | |
| | | | | | | | |
| TOTAL | | 100.0% | 0.547 | | | | |
| | | | | | | | |
| | | | | | | | |

| APPENDIX VIII.2: Spreadsheet template used to calculate benefit per sheep cover comb-shorn. | |
|---|---|
| | |
| NET BENEFITS ASSOCIATED WITH COVER COMB SHEARING | |
| (EXTRA COST PER SHEEP FOR COVER COMB SHEARING IS EXCLUDED HERE) | |
| | |
| PLS EWES | |
| | |
| REDUCTION IN LOSSES | |
| REDUCTION IN EWE LOSSES % | 1.0% |
| LAMBING % | 100.0% |
| LAMB LOSSES % | 4.0% |
| WOOL/LAMB (KG) | 0.7 |
| $/CULL EWE | 22.00 |
| $COSTS/EWE (e.g.animal health) | 1.20 |
| $/LAMB | 31.60 |
| $KG/LAMBS WOOL | 3.10 |
| $COSTS/LAMB (e.g.shear,animal health) | 1.70 |
| | |
| EWE BENEFIT ($) | 0.2080 |
| LAMB BENEFIT ($) | 0.3079 |
| BENEFIT - REDUCED LOSSES ($/EWE) | 0.5159 |
| | |
| FEED SAVINGS | |
| FEED INTAKE (KG DM/EWE/DAY) | 1.5 |
| FEED SAVING (% OF ABOVE AMOUNT) | 0.0% |
| DURATION OF SAVINGS (DAYS) | 15 |
| OPPORTUNITY COST OF FEED ($/KG DM) | 0.06 |
| | |
| BENEFIT - FEED SAVINGS ($/EWE) | 0.0000 |
| | |
| TOTAL BENEFIT/EWE | 0.5159 |
| | |
| | |
| EWE HOGGETS | |
| | |
| REDUCTION IN LOSSES | |
| REDUCTION IN EWE HGT LOSSES % | 1.0% |
| $/CULL EWE HGT | 36.95 |
| $COSTS/EWE HGT (e.g.animal health) | 1.00 |
| | |
| BENEFIT - REDUCED LOSSES ($/EH) | 0.3595 |
| | |
| FEED SAVINGS | |
| FEED INTAKE (KG DM/EWE HGT/DAY) | 1.0 |
| FEED SAVING (% OF ABOVE AMOUNT) | 0.0% |
| DURATION OF SAVINGS (DAYS) | 15 |
| OPPORTUNITY COST OF FEED ($/KG DM) | 0.06 |
| | |
| BENEFIT - FEED SAVINGS ($/EH) | 0.0000 |
| | |
| TOTAL BENEFIT/EWE HGT | 0.3595 |

| | |
|---|---|
| LAMBS | |
| | |
| REDUCTION IN LOSSES | |
| REDUCTION IN LAMB LOSSES % | 0.5% |
| $/LAMB | 31.60 |
| $COSTS/LAMB (e.g.animal health) | 0.50 |
| | |
| BENEFIT - REDUCED LOSSES ($/LAMB) | 0.1555 |
| | |
| FEED SAVINGS | |
| FEED INTAKE (KG DM/LAMB/DAY) | 0.8 |
| FEED SAVING (% OF ABOVE AMOUNT) | 0.0% |
| DURATION OF SAVINGS (DAYS) | 15 |
| OPPORTUNITY COST OF FEED ($/KG DM) | 0.06 |
| | |
| BENEFIT - FEED SAVINGS ($/LAMB) | 0.0000 |
| | |
| TOTAL BENEFIT/LAMB | 0.1555 |

| APPENDIX VIII.3: Spreadsheet template used for calculation of numbers of sheep cover comb-shorn. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR | 1995 | | | | | | | | | | |
| REGION | | N.Z. | | N.I. | S.I. | | Auck | East NI | Tar/Man | Mar/Can | South SI |
| OPEN NO. (000) | | 48816 | | 22406 | 26410 | | 6981 | 10542 | 4883 | 12097 | 14313 |
| NUMBER IN CLASS (000) | | | | | | | | | | | |
| Ewes | | 34557 | | 15458 | 19089 | | 4818 | 7269 | 3369 | 8658 | 10446 |
| 2 Tooths | | 8230 | | 3982 | 4257 | | 1248 | 1865 | 865 | 1847 | 2427 |
| MA Ewes | | 26322 | | 11476 | 14832 | | 3570 | 5404 | 2504 | 6811 | 8017 |
| E Hgts | | 9792 | | 4945 | 4859 | | 1546 | 2322 | 1073 | 2164 | 2705 |
| W Hgts | | 2665 | | 1589 | 1085 | | 483 | 761 | 352 | 631 | 432 |
| Wethers | | 1294 | | 166 | 1115 | | 56 | 73 | 35 | 520 | 593 |
| Rams | | 508 | | 249 | 261 | | 77 | 116 | 54 | 123 | 137 |
| NUMBER SHORN (000) | | | | | | | | | | | |
| No. Shorn | | 44095 | | 19619 | 24461 | | 6113 | 9233 | 4273 | 11130 | 13341 |
| No. Shorn Twice | | 14479 | | 11340 | 3285 | | 3542 | 5334 | 2460 | 1020 | 2344 |
| CHECK FOR PROPORTION SHORN | | | | NZ | | | NZ | NI | SI | | |
| 2 Tooths | | 0.9555 | | 0.9545 | | | 0.9544 | 0.9428 | 0.9653 | | |
| MA Ewes | | 0.9555 | | 0.9556 | | | 0.9556 | 0.9428 | 0.9656 | | |
| E Hgts | | 0.9555 | | 0.9540 | | | 0.9540 | 0.9428 | 0.9654 | | |
| W Hgts | | 0.9555 | | 0.9519 | | | 0.9524 | 0.9428 | 0.9669 | | |
| Wethers | | 0.9555 | | 0.9629 | | | 0.9627 | 0.9427 | 0.9656 | | |
| Rams | | 0.9555 | | 0.9544 | | | 0.9545 | 0.9428 | 0.9657 | | |
| No. Shorn (000) | | 46639 | | 21115 | 25509 | | 6567 | 9951 | 4604 | 11744 | 13755 |
| NO. SHORN (000) | | | | | | | | | | | |
| Total Ewes | | 33014 | | 14568 | 18438 | | 4532 | 6862 | 3177 | 8405 | 10038 |
| 2 Tooths | | 7864 | | 3752 | 4112 | | 1174 | 1760 | 815 | 1793 | 2333 |
| MA Ewes | | 25150 | | 10815 | 14326 | | 3359 | 5101 | 2362 | 6612 | 7705 |
| Total Ewes - x1 | | 23495 | | 6490 | 16843 | | 2009 | 3062 | 1425 | 7805 | 8993 |
| Total Ewes - x2 | | 9520 | | 8078 | 1596 | | 2524 | 3800 | 1752 | 600 | 1045 |
| E Hgts | | 9357 | | 4660 | 4694 | | 1455 | 2192 | 1012 | 2101 | 2600 |
| 2 Tooths - x2 | | 4959 | | 3262 | 1690 | | 1018 | 1535 | 708 | 420 | 1300 |
| W Hgts | | 2547 | | 1497 | 1048 | | 454 | 719 | 332 | 613 | 415 |
| Wethers | | 1236 | | 156 | 1076 | | 53 | 69 | 33 | 505 | 570 |
| Rams | | 485 | | 234 | 253 | | 73 | 109 | 51 | 120 | 132 |
| Lambs | | 21250 | | 12919 | 8427 | | 4087 | 5987 | 2804 | 3423 | 5074 |
| Ewe Shearings | | 39991 | | 21148 | 18985 | | 6602 | 9943 | 4598 | 8391 | 10669 |
| CHECK FOR NO. SHORN (000) | | | | NZ | | | NZ | NI | SI | | |
| Total Ewes | | 33014 | | 33006 | | | 33014 | 14571 | 18443 | | |
| 2 Tooths | | 7864 | | 7864 | | | 7876 | 3750 | 4126 | | |
| MA Ewes | | 25150 | | 25141 | | | 25138 | 10822 | 14317 | | |
| Total Ewes - x1 | | 23495 | | 23333 | | | 23295 | 6496 | 16799 | | |
| Total Ewes - x2 | | 9520 | | 9673 | | | 9719 | 8075 | 1644 | | |
| E Hgts | | 9357 | | 9354 | | | 9360 | 4659 | 4701 | | |
| 2 Tooths - x2 | | 4959 | | 4952 | | | 4981 | 3261 | 1720 | | |
| W Hgts | | 2547 | | 2546 | | | 2533 | 1505 | 1028 | | |
| Wethers | | 1236 | | 1233 | | | 1228 | 154 | 1074 | | |
| Rams | | 485 | | 487 | | | 485 | 233 | 252 | | |
| Lambs | | 21250 | | 21347 | | | 21375 | 12877 | 8497 | | |
| Ewe Shearings | | 39991 | | 40134 | | | 40203 | 21143 | 19060 | | |
| TO CONVERT EWE SHEARINGS TO EWES SHORN WHERE EWE SHEARING PROPORTION KNOWN (INCLUDES 2THS) | | | | | | | | | | | |
| WITH RESEARCH | | | | | | | | | | | |
| Ewe Shearing | | 0.245 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Ewes Shorn | | 0.334 | | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| WITHOUT RESEARCH | | | | | | | | | | | |
| Ewe Shearing | | 0.15 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Ewes Shorn | | 0.204 | | 0.000 | 0.000 | | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| PROPORTION SHEEP SHORN WITH COVER COMB | | | | | | | | | | | |
| WITH RESEARCH | | | | | | | | | | | |
| Ewes | | 0.33 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | | 0.11 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Other | | 0.1 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Lambs | | 0.001 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| WITHOUT RESEARCH | | | | | | | | | | | |
| Ewes | | 0.25 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | | 0.05 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Other | | 0.05 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Lambs | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NO. COVER COMB SHORN (000) | | | | | | | | | | | |
| WITH RESEARCH | | | | | | | | | | | |
| Ewes | | 10895 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | | 1029 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Other | | 427 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Lambs | | 21 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | |
| WITHOUT RESEARCH | | | | | | | | | | | |
| Ewes | | 8254 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | | 468 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Other | | 213 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Lambs | | 0 | | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | |
| TOTAL NO. COVER COMB SHORN IN NZ (000) | | | | | | | | | | | |
| WITH RESEARCH | | | | NZ | | | NZ | NI | SI | | |
| Ewes | | 10895 | | 0 | | | 0 | 0 | 0 | | |
| E Hoggets | | 1029 | | 0 | | | 0 | 0 | 0 | | |
| Other | | 427 | | 0 | | | 0 | 0 | 0 | | |
| Lambs | | 21 | | 0 | | | 0 | 0 | 0 | | |
| | | | | | | | | | | | |
| WITHOUT RESEARCH | | | | NZ | | | NZ | NI | SI | | |
| Ewes | | 8254 | | 0 | | | 0 | 0 | 0 | | |
| E Hoggets | | 468 | | 0 | | | 0 | 0 | 0 | | |
| Other | | 213 | | 0 | | | 0 | 0 | 0 | | |
| Lambs | | 0 | | 0 | | | 0 | 0 | 0 | | |

**APPENDIX VIII.4: Spreadsheet template to calculate the rates of return.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BASE YEAR | 1996 | | | | | | | | | | | | |
| YEAR | | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 |
| YEAR NUMBER | | -7 | -6 | -5 | -4 | -3 | -2 | -1 | 0 | 1 | 2 | 3 | 4 |
| COSTS | | | | | | | | | | | | | |
| Development | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Research | | 28122 | 39883 | 0 | 104916 | 0 | 54614 | 76596 | 0 | 0 | 0 | 0 | 0 |
| Extension | | 0 | 0 | 10000 | 10000 | 10000 | 10000 | 10000 | 10000 | 0 | 0 | 0 | 0 |
| OPEN NO. (000) | | 60568 | 57852 | 55162 | 52569 | 50298 | 49466 | 48816 | 48000 | 48000 | 48000 | 48000 | 48000 |
| % CC SHORN (EXCL LAMBS) | | | | | | | | | | | | | |
| With Research | | 9.92% | 12.23% | 14.75% | 21.57% | 23.21% | 24.29% | 25.30% | 26.07% | 26.41% | 26.75% | 27.08% | 27.42% |
| Without Research | | 9.92% | 10.67% | 11.49% | 13.00% | 13.76% | 14.17% | 14.54% | 14.74% | 14.69% | 14.64% | 14.59% | 14.54% |
| Difference | | 0.00% | 1.56% | 3.26% | 8.56% | 9.45% | 10.12% | 10.76% | 11.33% | 11.72% | 12.11% | 12.49% | 12.88% |
| SHEEP CC SHORN (000) | | | | | | | | | | | | | |
| WITH RESEARCH | | | | | | | | | | | | | |
| Ewes - PLS | | 5735 | 6650 | 7565 | 10310 | 10505 | 10700 | 10895 | 10988 | 11081 | 11174 | 11267 | 11362 |
| Ewes - FW | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | | 116 | 234 | 350 | 705 | 813 | 921 | 1029 | 1100 | 1170 | 1240 | 1310 | 1380 |
| Other | | 159 | 192 | 224 | 322 | 357 | 392 | 427 | 426 | 425 | 425 | 422 | 420 |
| Lambs | | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 58 | 95 | 132 | 170 | 209 |
| WITHOUT RESEARCH (000) | | | | | | | | | | | | | |
| Ewes - PLS | | 5735 | 5868 | 6000 | 6399 | 6467 | 6535 | 6603 | 6581 | 6559 | 6537 | 6515 | 6493 |
| Ewes - FW | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | | 116 | 143 | 170 | 252 | 261 | 271 | 281 | 280 | 279 | 278 | 277 | 276 |
| Other | | 159 | 164 | 169 | 184 | 193 | 203 | 213 | 213 | 212 | 212 | 211 | 210 |
| Lambs | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DIFFERENCE (000) | | | | | | | | | | | | | |
| Ewes - PLS | | 0 | 782 | 1565 | 3911 | 4038 | 4165 | 4292 | 4407 | 4522 | 4637 | 4752 | 4869 |
| Ewes - FW | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | | 0 | 91 | 180 | 453 | 552 | 650 | 748 | 820 | 891 | 962 | 1033 | 1104 |
| Other | | 0 | 28 | 55 | 138 | 164 | 189 | 214 | 213 | 213 | 213 | 211 | 210 |
| Lambs | | 0 | 0 | 0 | 0 | 0 | 0 | 21 | 58 | 95 | 132 | 170 | 209 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRODN COSTS/SHEEP | | | | | | | | | | | | |
| Ewes - PLS | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - FW | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - 8 Mth | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - 2 Shr | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| E Hoggets | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Other | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Lambs | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| | | | | | | | | | | | | |
| BENEFITS/SHEEP | | | | | | | | | | | | |
| Ewes - PLS | 0.522 | 0.522 | 0.534 | 0.534 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 |
| Other | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 |
| Lambs | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 |
| | | | | | | | | | | | | |
| PRODN COSTS (NET) | | | | | | | | | | | | |
| Ewes - PLS | 0 | 62560 | 125200 | 312860 | 323040 | 333200 | 343360 | 352560 | 361760 | 370960 | 380160 | 389520 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 0 | 7260 | 14400 | 36240 | 44160 | 52000 | 59840 | 65600 | 71260 | 76960 | 82640 | 88320 |
| Other | 0 | 2240 | 4400 | 11040 | 13120 | 15120 | 17120 | 17040 | 17040 | 17040 | 16880 | 16800 |
| Lambs | 0 | 0 | 0 | 0 | 0 | 0 | 1660 | 4640 | 7600 | 10560 | 13600 | 16720 |
| | | | | | | | | | | | | |
| BENEFIT (NET) | | | | | | | | | | | | |
| Ewes - PLS | 0 | 408204 | 835710 | 2088474 | 2208786 | 2278255 | 2347724 | 2410829 | 2473534 | 2536439 | 2599344 | 2663343 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 0 | 32714.5 | 64710 | 162853.5 | 198444 | 233675 | 268906 | 294790 | 320314.5 | 345839 | 371363.5 | 396888 |
| Other | 0 | 10066 | 19772.5 | 49611 | 58958 | 67945.5 | 76933 | 76573.5 | 76573.5 | 76573.5 | 75854.5 | 75495 |
| Lambs | 0 | 0 | 0 | 0 | 0 | 0 | 3265.5 | 9019 | 14772.5 | 20526 | 26435 | 32499.5 |
| | | | | | | | | | | | | |
| TOTAL COSTS | 28122 | 111963 | 154000 | 475076 | 390320 | 464934 | 508596 | 449840 | 457680 | 475520 | 493260 | 511360 |
| | | | | | | | | | | | | |
| TOTAL BENEFITS | 0 | 450984.5 | 920192.5 | 2300938.5 | 2466188 | 2579875.5 | 2696828.5 | 2791011.5 | 2885194.5 | 2979377.5 | 3072997 | 3168225.5 |
| | | | | | | | | | | | | |
| BENEFITS-COSTS | -28122 | 339021.5 | 766192.5 | 1825862.5 | 2075868 | 2114941.5 | 2188232.5 | 2341171.5 | 2427514.5 | 2503857.5 | 2579717 | 2656865.5 |
| | | | | | | | | | | | | |
| PRESENT VALUE | -39570 | 454321 | 977877 | 2219347 | 2403077 | 2331723 | 2297644 | 2341172 | 2311919 | 2271073 | 2228457 | 2185810 |
| | | | | | | | | | | | | |
| PV - COSTS | 39570 | 53447 | 12763 | 139681 | 11576 | 71237 | 90926 | 10000 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | |
| PV - BENEFITS | 0 | 507768 | 990640 | 2359028 | 2414653 | 2402960 | 2388570 | 2351172 | 2311919 | 2271073 | 2228457 | 2185810 |

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| APPENDIX VIII.4 | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BASE YEAR | | | | | | | | | | | | | |
| YEAR | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| YEAR NUMBER | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| COSTS | | | | | | | | | | | | | |
| Development | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Research | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Extension | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OPEN NO. (000) | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 |
| % CC SHORN (EXCL | | | | | | | | | | | | | |
| With Research | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% |
| Without Research | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% |
| Difference | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% |
| SHEEP CC SHORN ( | | | | | | | | | | | | | |
| WITH RESEARCH | | | | | | | | | | | | | |
| Ewes - PLS | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 |
| Other | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Lambs | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 |
| WITHOUT RESEAR | | | | | | | | | | | | | |
| Ewes - PLS | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 276 | 276 | 276 | 276 | 276 | 276 | 276 | 276 | 276 | 276 | 276 | 276 | 276 |
| Other | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 |
| Lambs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DIFFERENCE (000) | | | | | | | | | | | | | |
| Ewes - PLS | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 |
| Other | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 | 210 |
| Lambs | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 | 209 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PRODN COSTS/SHE | | | | | | | | | | | | | |
| Ewes - PLS | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - FW | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - 8 Mth | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - 2 Shr | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| E Hoggets | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Other | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Lambs | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| | | | | | | | | | | | | | |
| BENEFITS/SHEEP | | | | | | | | | | | | | |
| Ewes - PLS | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 |
| Other | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 |
| Lambs | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 |
| | | | | | | | | | | | | | |
| PRODN COSTS (NET | | | | | | | | | | | | | |
| Ewes - PLS | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 |
| Other | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 |
| Lambs | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 |
| | | | | | | | | | | | | | |
| BENEFIT (NET) | | | | | | | | | | | | | |
| Ewes - PLS | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 |
| Other | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 |
| Lambs | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 |
| | | | | | | | | | | | | | |
| TOTAL COSTS | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 |
| | | | | | | | | | | | | | |
| TOTAL BENEFITS | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 |
| | | | | | | | | | | | | | |
| BENEFITS-COSTS | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 |
| | | | | | | | | | | | | | |
| PRESENT VALUE | 2081724 | 1982594 | 1888185 | 1798271 | 1712639 | 1631085 | 1553414 | 1479442 | 1408993 | 1341 8 | 1277998 | 1217141 | 1159182 |
| | | | | | | | | | | | | | |
| PV - COSTS | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | | | | | | | |
| PV - BENEFITS | 2081724 | 1982594 | 1888185 | 1798271 | 1712639 | 1631085 | 1553414 | 1479442 | 1408993 | 1341898 | 1277998 | 1217141 | 1159182 |

| APPENDIX VIII.4 | | | | | | | |
|---|---|---|---|---|---|---|---|
| BASE YEAR | | | | | | | |
| YEAR | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
| YEAR NUMBER | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| COSTS | | | | | | | |
| Development | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Research | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Extension | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| OPEN NO. (000) | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 | 48000 |
| % CC SHORN (EXCL | | | | | | | |
| With Research | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% | 27.42% |
| Without Research | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% | 14.54% |
| Difference | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% | 12.88% |
| SHEEP CC SHORN ( | | | | | | | |
| WITH RESEARCH | | | | | | | |
| Ewes - PLS | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 | 11362 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 | 1380 |
| Other | 420 | 420 | 420 | 420 | 420 | 420 | 420 |
| Lambs | 209 | 209 | 209 | 209 | 209 | 209 | 209 |
| WITHOUT RESEAR( | | | | | | | |
| Ewes - PLS | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 | 6493 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 276 | 276 | 276 | 276 | 276 | 276 | 276 |
| Other | 210 | 210 | 210 | 210 | 210 | 210 | 210 |
| Lambs | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DIFFERENCE (000) | | | | | | | |
| Ewes - PLS | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 | 4869 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 | 1104 |
| Other | 210 | 210 | 210 | 210 | 210 | 210 | 210 |
| Lambs | 209 | 209 | 209 | 209 | 209 | 209 | 209 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| PRODN COSTS/SHEI | | | | | | | |
| Ewes - PLS | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - FW | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - 8 Mth | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Ewes - 2 Shr | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| E Hoggets | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Other | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| Lambs | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 | 0.08 |
| | | | | | | | |
| BENEFITS/SHEEP | | | | | | | |
| Ewes - PLS | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 | 0.547 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 |
| Other | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 | 0.3595 |
| Lambs | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 | 0.1555 |
| | | | | | | | |
| PRODN COSTS (NET | | | | | | | |
| Ewes - PLS | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 | 389520 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 | 88320 |
| O her | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 | 16800 |
| Lambs | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 | 16720 |
| | | | | | | | |
| BENEFIT (NET) | | | | | | | |
| Ewes - PLS | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 | 2663343 |
| Ewes - FW | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 8 Mth | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ewes - 2 Shr | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| E Hoggets | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 | 396888 |
| O her | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 | 75495 |
| Lambs | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 | 32499.5 |
| | | | | | | | |
| TOTAL COSTS | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 | 511360 |
| | | | | | | | |
| TOTAL BENEFITS | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 | 3168225.5 |
| | | | | | | | |
| BENEFITS-COSTS | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 | 2656865.5 |
| | | | | | | | |
| PRESENT VALUE | 1103982 | 1051412 | 1001345 | 953662 | 908249 | 864999 | 823809 |
| | | | | | | | |
| PV - COSTS | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | | | | | | |
| PV - BENEFITS | 1103982 | 1051412 | 1001345 | 953662 | 908249 | 864999 | 823809 |

| | |
|---|---|
| PARAMETER | |
| DISCOUNT RATE | 5% |
| | |
| RETURNS | |
| | |
| IRR TO 2020 | 1330.5% |
| IRR TO 2010 | 1330.5% |
| IRR TO 2005 | 1330.5% |
| IRR TO 2000 | 1330.5% |
| | |
| NPV TO 2020 | 49222870 |
| NPV TO 2010 | 38861092 |
| NPV TO 2005 | 31446261 |
| NPV TO 2000 | 21982848 |
| | |
| BCR TO 2020 | 115.69 |
| BCR TO 2010 | 91.54 |
| BCR TO 2005 | 74.27 |
| BCR TO 2000 | 52.22 |