REVIEW OF MARKETING AND AGRICULTURAL ECONOMICS
VOL. 48, No. 3 (*December*, 1980)

# Social Benefits of Serrated Tussock Control in New South Wales

D. T. Vere†, J. A. Sinden*, and M. H. Campbell†

Weeds are responsible for extensive annual losses of agricultural production although convincing estimates of such loss are largely unavailable, particularly in Australia. Recognition of the economic cost of weeds is important for a number of reasons which include the rationalization of weed control programmes and the direction of weeds research. Because of data deficiencies relating to extent and distribution, impact on production and the environment, and the spread potential of individual weed species, this area of weeds research has to date received little attention. In this paper, the concepts of economic surplus are utilized in a general social benefit framework to assess the economic importance of serrated tussock (*Nassella trichotoma*), the major pasture weed of the New South Wales tablelands. The widespread control of serrated tussock under pasture improvement would result in substantial increases in social benefits at both the state and national levels. Some of the important questions surrounding the social benefit model and its practical application are also discussed.

## 1 Introduction

The control of pests and diseases is a major economic problem confronting modern agriculture. Aggregate production losses due to animal and insect pests, plant and animal diseases, and to weeds are suspected to be substantial although credible estimates of such losses are few. Because of the huge variety of pests, diseases and weeds, and the large range of agricultural activities whose productivity they affect, the annual loss of gross farm production is difficult to estimate at the national level. On a global basis, this exercise would be virtually impossible although it has been stated that more than half of the world's potential production of agricultural commodities is annually destroyed by pests of all kinds (Pimentel 1976).

Whilst many factors contribute to loss of agricultural production, weeds of crops and pastures are of major economic significance because they reduce production and require large amounts of finance, both private and public, for their control. However, for various reasons, production losses caused by weeds are not fully recognized and in the main, are poorly documented. It seems that unlike other pests, weeds are taken for granted and since they are so common and widespread, their significance in terms of production losses and costs of control are not generally appreciated (Anon. 1968). It seems certain that most weed control strategies have evolved without full knowledge of the actual losses to be prevented and of the relevant economic factors involved (Chiarappa *et al* 1972), and further that proven control measures are coming under increasing economic pressure (Geier 1978; Vere and Auld 1979).

* Senior Lecturer in Agricultural Economics, University of New England, Armidale.

† Respectively, Senior Economist and Principal Research Scientist, New South Wales Department of Agriculture, Orange.

The authors wish to acknowledge the useful comments and suggestions of the *Review* referees and Editors which were passed on an earlier draft of this paper. Any remaining errors are the responsibility of the authors.

Recognition of the economic costs of weeds to agriculture is important for a number of reasons, the major ones being to objectively assess the status of plants as weeds, to rationalize weed control programmes, for directing weed research, and to reduce the market risk of developing new herbicides. To date, this area of weeds research has received scant attention, mainly because of data deficiencies relating to extent and distribution, impact on production and the environment, and spread potential.

In Australia, weeds assume particular economic importance because of the extensive nature of much of our agricultural production and the low yields per unit land area relative to those of other modern agricultural systems. However, in this country there have been few attempts to establish either the economics of controlling certain weeds or to estimate the extent of the economic losses they cause. In 1976, a survey of Australian weed research programmes at Australian universities showed a minimal economic input (Blacklow 1976). More recently, Trumble (1978) noted that landholders were often compelled to control weeds whose noxious status had been determined on the basis of questionable qualitative evidence rather than on quantitative economic information; a concern echoed by Quinlivan (1972).

Serrated tussock (*Nassella trichotoma*) is the most important perennial grass weed of pastures on the central and southern tablelands of New South Wales and is regarded as being the weed causing greater reductions in carrying capacity than any other pasture weed in Australia (Parsons 1973). In an attempt to quantify the potential benefits from the widespread control of serrated tussock, Vere and Campbell (1979) estimated that an additional 7.6 million kilograms of greasy Merino wool valued at $11.8 million could be annually produced by replacing all heavy and moderate infestations of the weed with improved pastures. That estimate was based on average stocking rates and wool cuts on improved pastures for individual shires throughout the central and southern tablelands. Not considered in that estimate were the important market and resource allocation effects that may result from the widespread adoption of serrated tussock control technology.

The general social benefit model incorporating the concepts of economic surplus provides an appropriate framework in which the aggregate social welfare effects of widespread pest control in agriculture can be assessed. The purpose of this paper is to demonstrate the use of this approach in assessing the economic importance of an important weed species (serrated tussock).

## 2 Weeds and Economic Loss

Weeds cause economic loss in a number of ways in agriculture. The major areas are the reductions in the production and quality of crop, forest and livestock products resulting from weed infestations, and from the large amounts of money that are annually spent on their control by both private and public parties. In crops, weeds reduce yields, contaminate produce, make harvesting difficult and increase the incidence of disease. The costs of herbicides and cultivation techniques used in weed control also represent a loss because such expenditure would be unnecessary in the absence of weeds. In grazing situations, the major economic effect of weeds is to reduce the carrying capacities of both improved and unimproved pastures, which will cause the land resource to be utilized at less than its optimal potential. Certain species are also toxic to stock, cause injury to animals, or contaminate animal products such as wool and skins.

Other areas of loss caused by weeds are more difficult to quantify and include the external costs that certain species impose because of their ability to spread and threaten the productivity of adjacent lands, and the degradation of recreational and public facilities.

The main determinants of production loss are population densities, impact on yield, spread potential and where pastures are concerned, whether the particular weed is short lived or is a perennial. Perennial weed species represent a dynamic economic problem because they are ever present, most are capable of rapid spread in both improved and unimproved pastures and many of the important species have negligible grazing value to stock. Alternatively, some annual or semi-annual species may provide valuable grazing at certain stages of their growth cycle, causing contention amongst landholders as to the proclaimed noxious status of such weeds. In most instances with non-perennial weeds, their economic impact largely depends on how their growth cycle corresponds to livestock management cycles and pasture demand.

Despite the fact that weeds and weed control efforts are common to most Australian agricultural practices, there is an overall lack of quantitative information as to their economic importance. Some insight into this importance might be gained from estimates which have been made in other developed economies. For example, the United States Department of Agriculture (1965) estimated that the annual loss of production caused by weeds in crops, pastures and rangelands in the U.S.A. averaged $US2,460 million over the period 1951–60, while a further $US2,551 million was annually spent on their control. Specifically, annual losses were valued at $US1,543.4 million in field crops and at $US632.3 million in pastures and rangelands. This is not to suggest that losses would be as great in Australia, only that they would bear some degree of relatively because of similarities in the systems of production.

## 3 Establishing the Economic Importance of Weeds

The economic importance of weeds in agriculture is best considered in terms of the effects on welfare, both private and social, that their presence or control engenders. In its simplest sense, social welfare involves the aggregation of individual preferences and utilities into a social welfare function which reflects society's preferences for alternate allocations of goods and services[1]. Undesirable effects on social welfare result from weed infestations because they cause the land resource to be utilized and developed at less than its optimal potential and restrict the supply of agricultural products available to the market.

Serrated tussock imposes external costs on landholders because of its ability to rapidly spread and proliferate (Vere and Campbell 1979), and this results in differences between the level of control undertaken privately and that which is socially desirable, *i.e.*, where the external costs associated with weed spread are internalized. Because the levels of private and social benefits and costs from control will also differ, it is proper to examine the benefits and costs of serrated tussock control in a social rather than a private context.

[1] It is not our intention to further discuss the theory, complexities and problems (for example the problems of aggregation) of social welfare analysis as they have been well treated in a number of text books and papers (see for example, Sinden and Worrell 1979).

The general social benefit model which incorporates the concept of economic surplus, provides an appropriate framework for the assessment of the social benefits and costs of an extensive weed control programme. The concept of economic surplus and its application is developed in the following section.

## 3.1 The concept of economic surplus

Despite the controversy surrounding its use, there has been increased application of the concept of economic surplus in the economic evaluation of public policies and programmes[2]. Economic surplus essentially consists of two elements—consumers' surplus and producers' surplus. Consumers' surplus is the difference between the maximum price that consumers are willing to pay and that which has to be paid for the commodity. Producers' surplus is more difficult to define and in fact, some doubt has been expressed as to its validity as a welfare measure (for example, Mishan 1968), and that it is more appropriate to consider this surplus in terms of economic rent. Whatever the appropriate terminology might be, this area of suplus is generally assumed to be the difference between the price received by producers for a particular commodity and the costs of producing it, *i.e.*, the difference between the price producers are willing to accept and that which they actually receive. Social benefit is obtained by summing the areas of consumers' surplus and producers' surplus.

The social welfare effects of weeds or weed control relate to the shifts in the supply curve for the commodity or commodities affected. Supply restrictions and social welfare losses will result from weed infestations if the yield effects are sufficiently significant. Alternatively, a widespread control programme will increase supply and social welfare gains, assuming land use patterns remain relatively unchanged. The method of assessing social gains and losses incorporates the principles of economic surplus outlined above and involves estimation of the potential social welfare effects of supply shifts resulting from weed infestations or their control. A weed would therefore have to exert a measurable impact on social welfare if it was to assume economic importance.

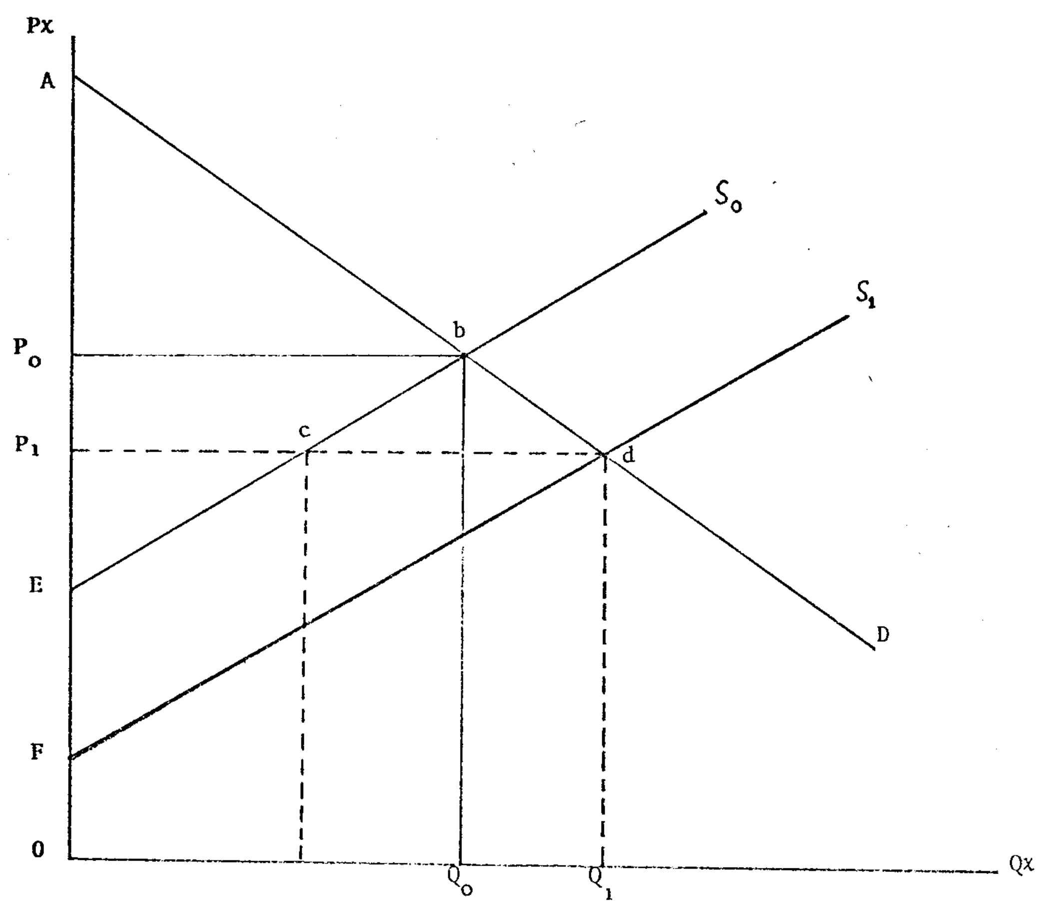
## 3.2 The general social benefit model

The major social welfare effect of a weed is through reduced supply enforced by yield reduction and product damage. This restricts the production available for both domestic and export consumption and reduces both consumers' and producers' surpluses. To illustrate, consider the situation where infestations of a weed restrict the production of commodity $\chi$ (Figure 1).

In Figure 1, $S_0$ is the short run supply or aggregate marginal social cost curve of production for $\chi$. Production of $\chi$ is restricted to $Q_0$ because of the presence of the weed which increases the average costs of production and reduces the returns per dollar invested. Total social benefits and costs from the production of $\chi$ are given by the areas $OAbQ_0$ and $OEbQ_0$ respectively. Social benefit is the area $EAb$, which includes both the areas of consumers' surplus $P_0Ab$ and of producers' surplus $EP_0b$.

[2] The range of theoretical and practical problems of application have been well covered by, for example, Currie *et al.* (1971), Mishan (1968), and Sinden and Worrell (1979). Here we discuss the problems specific to this application.

*Figure* 1: *Change in social benefits from weed control*




The economic importance of the weed in relation to product $\chi$ can now be demonstrated if it is assumed that a composite control programme has increased the supply of $\chi$ from $S_0$ to $S_1$. Social benefit under control is now given by the area *FAd*. Therefore the increase in social welfare resulting from the control of the weed (as measured by the change in social benefits) is the difference between the areas *FAd* and *EAb* which is the area *FEbd*. This area represents the potential gains to society from the control of the weed.

## 4 Application of Model

In this section, an estimate is made of the economic benefits which would flow from the widespread control of serrated tussock on the New South Wales tablelands. A comparison of the potential social benefits and costs from the control of serrated tussock is also made.

### 4.1 Choice of estimator

The literature contains a number of models which have been developed to estimate the social benefits from various forms of public investment in agriculture and elsewhere. In the agricultural context, the concept of economic surplus has been used to determine the potential benefits from public investment in research and development (for example, Akino and Hayami 1975; Ayer and Schuh 1972; Hayami and Peterson 1972; Griliches 1958; and Nagy and Furtan 1978)[3], in policy and international trade (for example, Parish 1962; Johnson 1965; and Wallace 1962), and in disease and pest control (for example, Emerson and Plato 1978; and Fischer 1968)[4].

The social benefit approach has been applied in essentially two broad areas:

(i) in the *ex ante* assessment of the potential social benefits that might result from the adoption of an innovation, policy, or pest control programme;

(ii) in the *ex post* assessment of the social benefits resulting from existing public investment programmes or policies in agriculture.

Of course, it can be argued that the existence of externalities (which are probable in the context of agricultural weed control) will invalidate the use of the social benefit approach because of the competitive assumptions underlying the general social benefit model. It is unlikely that empirical estimates of aggregate supply and demand functions for products such as wool, will include estimates of the effects of externalities because of the manner in which such functions are often obtained[5]. Given that externalities are necessary considerations in the context of this analysis, then the social benefits from serrated tussock control (as measured through the changes in economic surplus) may be subject to bias. We recognize this problem of potential bias in any benefit estimates so obtained and suggest that it may be overcome by sensitizing the critical parameter values used in the subsequent application of the model.

Assuming that the problems referred to above can be satisfactorily overcome, the social benefit approach is suited to the question of assessing the economic importance of weeds because weeds and their control directly influence the production from a given area of land in a way similar to the adoption of an innovation or policy. Assessment can be made either on the basis of the social losses caused by weeds in crops and pastures, or of the social benefits resulting from their widespread control. The question now concerns the choice of the most appropriate estimator.

Of the various forms of the social benefit model available, the model reported by Akino and Hayami (1975) to estimate the social benefits and costs from rice breeding research in Japan has been used here to assess the potential social benefits from the control of serrated tussock in New South Wales. There are several reasons why the Akino and Hayami model seems appropriate for use in the weed control context.

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[3] A comprehensive review of the methods used to evaluate the returns to agricultural research is to be found in Norton and Davis (1979).

[4] It should be recognized that most of these applications have been in the partial equilibrium context and that the validity of this approach has been challenged by some (Little 1950), although it has been strongly supported by others (for example, Hicks 1940–41).

[5] For example, a social demand function for weed control might be obtained through the aggregation of the individual marginal value product curves of landholders (for weed control). This will tend to underestimate the true social demand function for weed control since the impact of external or spillover effects in this instance are unlikely to be taken into account.

The most important concerns the nature of the supply shift assumed to result from weed control. The importance of the type of supply shift resulting from the adoption of an innovation (such as weed control) has been highlighted in recent papers by Lindner and Jarrett (1978) and Sarhangi *et al.* (1977). In the former, the authors emphasized the dangers of making unqualified *a priori* generalizations about the nature of the supply shift and demonstrated how different types of shifts influenced the size of the estimated benefits[6]. It was concluded that a divergent shift of the supply curve was more likely to result from a biological innovation if it could be evenly diffused amongst producers, where a divergent shift includes all cases where the absolute vertical distance between the supply curves increases as the quantity supplied increases. Weed control is a biological innovation and control recommendations are readily available to all producers. Additionally, if it can be assumed that the majority of landholders affected by serrated tussock are low cost (or "inframarginal") producers, then the resulting supply shift from weed control is likely to be ". . . highly divergent, if not pivotal" (Lindner and Jarrett 1978).

Whether or not landholders affected by serrated tussock are marginal or inframarginal producers is debatable since it can be argued that the weed reduces potential production and increases the average costs of producing a unit of output compared to a weed free pasture. Alternatively, because country heavily infested with serrated tussock can only support very low stock numbers, input usage is low (for example, there will be no fertilizer or pasture costs), and so are the average costs per unit of commodity produced relative to wool production from improved pastures. For the purpose of this analysis, it is assumed that the latter situation holds and thus it is reasonable to assume a pivotal supply shift would result from the control of serrated tussock, and that the area of producers' surplus is a measure of the aggregate surplus enjoyed by non-marginal or low cost producers (Currie *et al.* 1971, p. 755).

The basic model used by Akino and Hayami (1975) is illustrated in Figure 2. The underlying assumptions of their model are market equilibrium[7], constant elasticities of supply and demand, no imports, and that a pivotal shift of the supply curve will result from producer adoption of higher yielding rice varieties.

The returns to research, measured in terms of the changes in consumers' and producers' surpluses resulting from an outward shift in the supply curve for rice were estimated as follows:

*change in consumers' surplus* is given by the area $abc$ plus the area $bP_nP_0c$

$$abc = \tfrac{1}{2} p_0 q_0 \frac{[k(1 + \delta)]^2}{\delta + \eta}$$

$$bP_nP_0c = \frac{p_0 q_0\, k(1 + \delta)}{\delta + \eta} \left[ 1 - \frac{\tfrac{1}{2}k(1 + \delta)\eta}{\delta + \eta} - \tfrac{1}{2}k(1 + \delta) \right]$$

*change in producers' surplus* is given by the area $aOc$ less the area $bP_nP_oc$

$$aOc = k\, p_o q_o$$

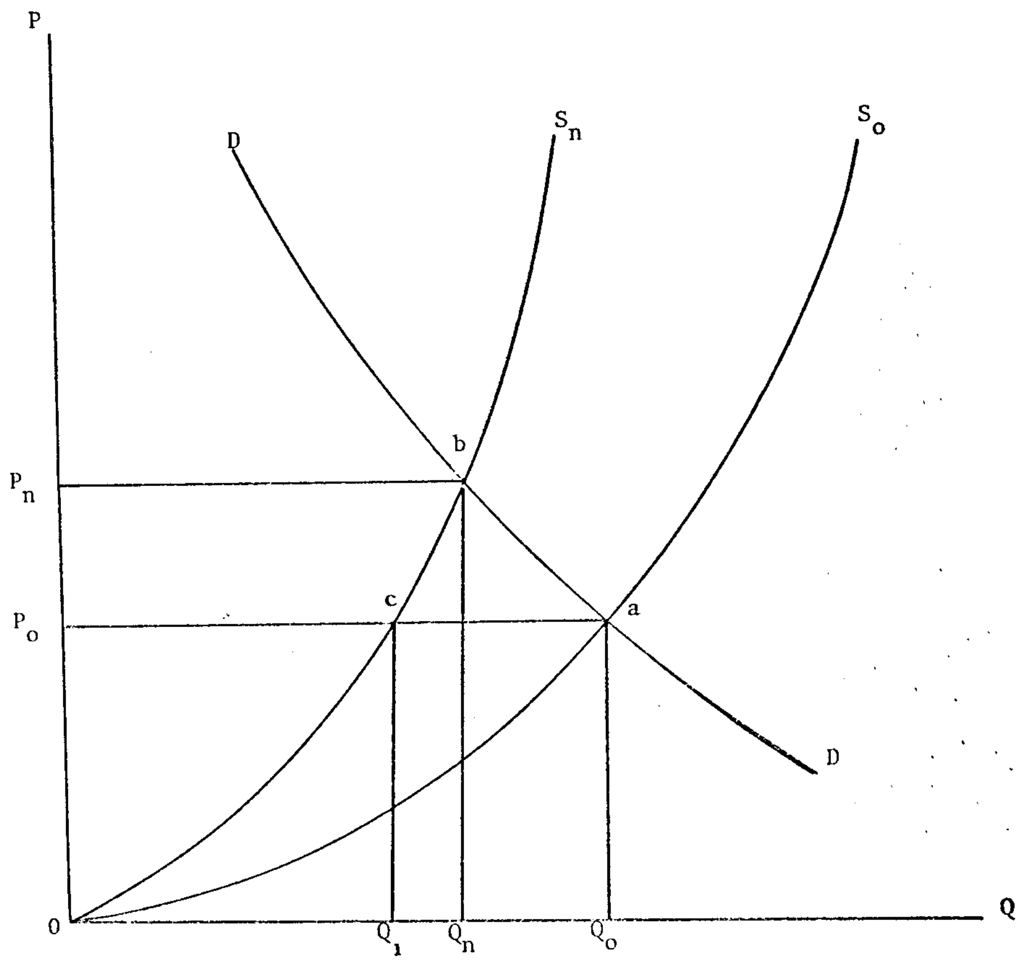
[6] The mathematical accuracy of the Lindner and Jarrett approach has been subsequently questioned (Rose 1980; Wise and Fell 1980).

[7] We recognize that in the case of wool, the market activities of the Australian Wool Corporation may in fact lead to market disequilibrium.

where

$k$ = a measure of shift of the supply curve
$p_o$ and $q_o$ = the annual price and quantity marketed
$\delta$ and $\eta$ = the price elasticities of supply and demand for the commodity.

*Figure 2: Social returns from the adoption of a biological innovation*




In applying these estimators to the example of serrated tussock in New South Wales, it is assumed that the widespread control of the weed will result in an outward shift in the supply function for the commodity in question (wool).

### 4.2 Data and assumptions

Data required for the assessment include extent and distribution of serrated tussock throughout the tablelands areas of New South Wales, and estimates of the production increases that would result following the weed's control. Extent and distribution data are available from Campbell (1977) whilst the potential supply increase resulting from the control of serrated tussock has been recently estimated by Vere and Campbell (1979). Wool is the assumed product and the production increase following control is assessed in terms of greasy wool production from Merino wethers (Table 1).

The value of $p_0$ is assumed to be 200 cents per kg greasy—the approximate average greasy wool price for 21 micron Merino fleece over the 1970's. Quantity $q_0$ is estimated at both the regional (central and southern tablelands of New South Wales) and national levels at 27.386 and 735.386 thousand kg respectively, which represent both the estimated increase in greasy wool production that would result from the control of serrated tussock and the average national level of Merino wool production over 1975–6 to 1977–8.

*Table 1: Area and Distribution of Major Infestations of Serrated Tussock in New South Wales and Estimated Supply Increase from Control*

| Shire | Area of tussock[a] | Average level of merino wool production[b] | Estimated production post-control[c] |
|---|---|---|---|
| | hectares | (1 000 kg) | (1 000 kg) |
| Abercrombie . . . . | 45 300 | 1 681 | 3 374 |
| Blaxland . . . . . . | 7 600 | 485 | 788 |
| Canobolas . . . . . . | 9 000 | 921 | 1 413 |
| Crookwell . . . . . . | 33 200 | 3 531 | 4 716 |
| Gunning . . . . . . | 2 400 | 1 808 | 1 890 |
| Imlay . . . . . . . . | 300 | 64 | 74 |
| Lyndhurst . . . . . . | 3 200 | 1 193 | 1 682 |
| Mittagong . . . . . . / Wingecarribee . . . . } | 48 000 | 111 | 1 623 |
| Monaro . . . . . . | 7 200 | 1 703 | 1 916 |
| Mulwaree . . . . . . | 16 600 | 2 541 | 3 444 |
| Oberon . . . . . . | 14 200 | 1 227 | 1 971 |
| Snowy River . . . . . . | 26 200 | 2 129 | 2 656 |
| Tallaganda . . . . . . | 4 300 | 635 | 771 |
| Turon . . . . . . | 340 | 959 | 1 068 |
| Totals . . . . . . | 217 840 | 18 988 | 27 386 |

[a] Source: Campbell (1977).

[b] Source: Australian Bureau of Statistics: Handbook of Local Statistics.

[c] Source: Vere and Campbell (1979).

Following the definition by Nagy and Furtan (1978), $k$ represents the percentage difference in yield between control and non-control. This variable is estimated at both the regional and national levels as follows:

$$\textit{regional level:}\quad k = [(27.386 - 18.988)/18.988] = 0.442$$

$$\textit{national level:}\quad k = [(735.386 - 708.00)/708.00] = 0.039$$

As we have suggested previously, a likely downward bias in the supply and demand parameters will cause the subsequent benefits to be underestimated. Accordingly, a range of values for $\delta$ and $\eta$ (the price elasticities of supply and demand for wool) are assumed based on a summary of elasticity estimates from a number of studies of the Australian wool market reported by Quilkey (1970).

## 4.3 Application

### 4.3.1. *Benefits*

Estimates of the annual social benefits that might result from the widespread control of serrated tussock in New South Wales for a range of values for $\delta$ and $\eta$ and for two estimates of $k$, are contained in Table 2. The estimated benefits are derived from the formulae for the areas of consumers' and producers' surpluses reported by Akino and Hayami (1975), as given in section 4.1.

*Table 2: Estimated Annual Social Benefits from the Control of Serrated Tussock in New South Wales*

| Price elasticity of supply ($\delta$) | Price elasticity demand ($\eta$) | Changes in consumers' surplus | Changes in producers' surplus | Total social benefits |
|---|---|---|---|---|
| | | $m | $m | $m |
| *Regional level* ($k$ = 0.442) | | | | |
| .1 .. .. .. .. .. | .2 | 74.377 | −28.588 | 45.789 |
| .2 .. .. .. .. .. | .3 | 48.857 | −9.397 | 39.460 |
| .3 .. .. .. .. .. | .4 | 37.577 | −0.451 | 37.126 |
| .4 .. .. .. .. .. | .5 | 31.186 | 4.675 | 35.861 |
| .6 .. .. .. .. .. | .6 | 26.572 | 9.051 | 35.623 |
| .8 .. .. .. .. .. | .7 | 23.659 | 12.106 | 35.765 |
| 1.0 .. .. .. .. .. | .8 | 21.616 | 14.482 | 36.098 |
| *National level* ($k$ = 0.039) | | | | |
| .1 .. .. .. .. .. | .2 | 207.406 | −145.535 | 61.871 |
| .2 .. .. .. .. .. | .3 | 135.736 | −75.155 | 60.581 |
| .3 .. .. .. .. .. | .4 | 104.986 | −44.926 | 60.060 |
| .4 .. .. .. .. .. | .5 | 87.915 | −28.119 | 59.796 |
| .6 .. .. .. .. .. | .6 | 75.287 | −15.541 | 59.746 |
| .8 .. .. .. .. .. | .7 | 67.703 | −7.927 | 59.776 |
| 1.0 .. .. .. .. .. | .8 | 62.879 | −3.033 | 59.846 |

The level of total estimated social benefit is seen to be largely insensitive to the assumed values for $\delta$ and $\eta$, although, the level of consumers' and producers' surpluses are strongly influenced by the assumed elasticity values. These results are consistent with the finding of Akino and Hayami. In the case of rice breeding, the relative magnitude of the changes in both consumers' and producers' surpluses was critically dependent on the values of $\delta$ and $\eta$, whilst the change in total social benefits was relatively insensitive since $k$ was only a small fraction of total output. This certainly holds here if the benefits from serrated tussock control are considered in the national context where $k$ represents less than 4 per cent of total national wool production. In this instance, the level of total social benefit is most insensitive to changes in the values for $\delta$ and $\eta$. It is also the case at the regional level even though $k$ represents a significant proportion of total regional output.

### 4.3.2. *Costs*

Serrated tussock can only be effectively and permanently controlled by replacing it with improved pastures (Campbell 1977). The costs of the widespread control of the weed in New South Wales therefore include those of the initial pasture improvement of infested areas, the annual pasture maintenance costs, costs of superphosphate application, and the continual removal of regenerating tussock seedlings up to the point at which tussock seed reservoirs in the soil have been depleted[8].

In order to estimate the monetary costs of serrated tussock control, it is assumed that a public authority is responsible for the initiation and supervision of the control programme, although it is not our intention to further develop a case for such intervention in control. It is also assumed that the initial pasture improvement of the total estimated area of heavy and moderate infestations can be effected in the first year of a control programme requiring 10 years to the point at which the established pastures are sufficiently mature and competitive to prevent tussock re-invasion. Additionally, an allowance for the risk of the pastures failing to control a proportion of the total area of infestation treated is made in the fifth year of the control programme (and is arbitrarily assumed to be 25 per cent of the costs of the initial control of the total area).

The estimated annual benefits and costs from the control of serrated tussock in New South Wales are projected forward over a 10 year period using a 10 per cent rate of discount (Table 3). Total annual social benefits are assumed to be $36 million and $60 million at the regional and national levels respectively (Table 2). The ratio of social benefits to social costs at both the regional and national levels can be established thus:

$$\textit{regional social benefit-cost ratio} = 221.20/34.23 = 6.5{:}1$$

$$\textit{national social benefit-cost ratio} = 368.67/34.23 = 10.8{:}1$$

## 5 Discussion

Our primary intention has been to demonstrate the use of the general social benefit model in assessing the economic consequences of the continued proliferation or the control of agricultural pests such as weeds. The preceding analysis has concerned the control of serrated tussock on the New South Wales tablelands. The economic importance of serrated tussock in New South Wales is assumed to be equivalent to the net social benefits that would result from the extensive control of the weed, where net social benefit approximates the change in the area of economic surplus less the monetary costs of control. Estimation of the absolute levels of social benefits and costs and the subsequent benefit-cost ratios has been a secondary purpose because such estimates are necessarily based on those assumptions and parameters which seem most relevant at the time. Nevertheless, the estimated benefit-cost ratios (6.5:1 and 10.8:1 at the regional and national levels respectively) indicate that the extensive control of serrated tussock will result in substantial gains in net social benefits at both the regional and national levels, implying that the production and consumption potential of society will increase if the weed is controlled.

[8] A full costing of the recommendations for the control of serrated tussock based on various soil fertility and rainfall situations is available in Vere *et al.* (1981).

The measured gain in total social benefit includes the increases in both consumers' and producers' surpluses following the control of serrated tussock. Gains in consumers' surplus result from the post-control production increases which become available for domestic consumption and export. This gain represents the willingness of consumers to pay for weed control (Emerson and Plato 1978). Gains in producers' surplus accrue from the increased returns from the resources used in production due to lower average costs per unit output and the increased quantities marketed. The gain in net social benefit can be interpreted as being equivalent to society's willingness to pay for the control of serrated tussock and hence, the social economic importance of the weed in New South Wales.

*Table 3: Projected Annual Benefits and Costs for the Control of Serrated Tussock in New South Wales*

| Year | Annual social benefits | Present values at 10 per cent | Annual social costs[a] | Present values at 10 per cent | Annual net social benefits |
|---|---|---|---|---|---|
| | $m | $m | $m | $m | $m |
| *Regional level—* | | | | | |
| 1 .. .. .. | 36.000 | 32.727 | 16.706 | 15.187 | 17.540 |
| 2 .. .. .. | 36.000 | 29.750 | 4.311 | 3.562 | 26.188 |
| 3 .. .. .. | 36.000 | 27.047 | 4.311 | 3.239 | 23.808 |
| 4 .. .. .. | 36.000 | 24.588 | 2.638 | 1.802 | 22.786 |
| 5 .. .. .. | 36.000 | 22.352 | 6.814 | 4.231 | 18.121 |
| 6 .. .. .. | 36.000 | 20.322 | 2.638 | 1.489 | 18.833 |
| 7 .. .. .. | 36.000 | 18.475 | 2.638 | 1.353 | 17.122 |
| 8 .. .. .. | 36.000 | 16.794 | 2.638 | 1.231 | 15.563 |
| 9 .. .. .. | 36.000 | 15.267 | 2.638 | 1.119 | 14.148 |
| 10 .. .. .. | 36.000 | 13.878 | 2.638 | 1.017 | 12.861 |
| Totals .. | .. | 221.200 | .. | 34.230 | 186.970 |
| *National level—* | | | | | |
| 1 .. .. .. | 60.000 | 54.546 | 16.706 | 15.187 | 39.359 |
| 2 .. .. .. | 60.000 | 49.584 | 4.311 | 3.562 | 46.022 |
| 3 .. .. .. | 60.000 | 45.078 | 4.311 | 3.239 | 41.839 |
| 4 .. .. .. | 60.000 | 40.980 | 2.638 | 1.802 | 39.178 |
| 5 .. .. .. | 60.000 | 37.254 | 6.814 | 4.231 | 33.023 |
| 6 .. .. .. | 60.000 | 33.870 | 2.638 | 1.489 | 32.381 |
| 7 .. .. .. | 60.000 | 30.792 | 2.638 | 1.353 | 29.439 |
| 8 .. .. .. | 60.000 | 27.990 | 2.638 | 1.231 | 26.759 |
| 9 .. .. .. | 60.000 | 25.446 | 2.638 | 1.119 | 24.327 |
| 10 .. .. .. | 60.000 | 23.130 | 2.638 | 1.017 | 22.113 |
| Totals .. | .. | 368.670 | .. | 34.230 | 334.440 |

[a] Source: Vere *et al.* (1980).

Estimation of the potential social gains from extensive pest control in general, raises several questions which are sometimes difficult to resolve in specific instances (such as the control of serrated tussock), largely because of the assumptions which have to be made in such assessments. The more important of these questions in the context of serrated tussock control concern the equity distribution of the social benefits from control, how a widespread control programme might be implemented, and how it should be financed. These questions are discussed in turn.

### 5.1 Distribution of benefits

An important consideration in any social cost-benefit analysis involving both producers and consumers is the relative gains by each group[9]. From Table 2, consumers are seen to capture most of the total social benefit when the supply and demand elasticity estimates are low, whilst producers increasingly gain as the elasticity values increase. Akino and Hayami (1975) concluded that producers stand to gain a greater share of total social benefit under conditions of a competitive demand and a non-competitive supply[10]. However, Australian wool production is characterized by many producers and a relatively inelastic supply and thus on this basis and the estimates reported in Table 2, it seems likely that consumers would derive the most benefit from a serrated tussock control programme. The question now becomes which consumers?

It can be argued that the increased production of a heavily export orientated commodity (such as Australian wool) would not generate a domestic consumers' surplus and therefore the gains in total social benefit will largely accrue to domestic producers and foreign consumers. If this is realistic then the gains to society from the control of serrated tussock will be given by the area *aOc*, which generates levels of total annual social benefit equivalent to \$24.21 and \$57.36 million on both a regional and national basis respectively. Gains to foreign consumers are not considered in the analysis since the model does not distinguish between them and domestic consumers.

A complexity now arises under which consumers theoretically capture the major share of the gains from a serrated tussock control programme (Table 2) but it might certainly be argued that producers in the tussock areas would in fact be the major beneficiaries. A similar problem was addressed by Emerson and Plato (1978) in their recent study of public investment in weed control in the United States, and we feel that their conclusions are relevant to the question of serrated tussock in New South Wales. The authors concluded that the possibility of producers being the major beneficiaries of a weed control programme was based on extremely short run assumptions. Pure economic profits accruing to producers through increased production from weed control would be rapidly bid away by the entry of new resources and thus public investment decisions should be based on long run considerations. Although public weed control imposes costs on tax payers, Emerson and Plato stated that a much greater benefit flows to consumers due to reduced weed spread which allows increased production for domestic consumption and export. If production increases are largely consumed domestically then domestic consumers' surplus considerations are relevant. If production increases are mainly exported, then society benefits from additional foreign exchange earnings. The conclusions of Emerson and Plato therefore imply that consumers are the principal long run beneficiaries of a general weed control programme.

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[9] The conditions under which productivity improvements (such as would result from weed control) benefit producers as well as consumers, or fail to do so, have been discussed by Duncan and Tisdell (1971).

[10] They concluded that social gains from a shift in the supply curve would be totally captured by producers when demand was infinitely elastic, and conversely when demand was inelastic and supply competitive.

### 5.2 Implementing and financing a control programme

Whilst it has not been our intention to fully develop a case for control based on public intervention, it seems likely that such intervention may be desirable to facilitate the extensive control of serrated tussock. Methods by which such control might be initiated and financed have been discussed by Vere and Campbell (1979) and include the provision of low interest loans to landholders to enable them to effect control, the supervision and development of individual problem properties, the provision of assistance to landholders in the form of subsidies and taxation concessions for pasture improvement, afforestation, and the revitalization of the activities of local weed control councils. Because of the extent and current importance of the serrated tussock problem and its varying impact between individual properties and districts throughout the New South Wales tablelands, there is an overall need for the formulation of a co-ordinated control programme embracing the suggestions outlined above. Public involvement in serrated tussock control therefore seems necessary. The grounds for public intervention in the control of agricultural pests in general have been discussed by Johnston (1975) and by Menz and Auld (1977) in specific reference to weeds. These grounds include producers' ignorance of the private and social benefits of control, cost economies as the scale of the control operation increases, and the existence of externalities.

If Australian consumers can be shown to be the long run beneficiaries of serrated tussock control then it is they who should be called upon to finance a control programme. On the other hand, we recognize the viewpoint that producers may derive the greatest benefit in reality and therefore should be the major contributors to the costs of the control of the weed; albeit with some form of Government assistance. We make no conclusion as to who should pay for the control of serrated tussock in New South Wales. Whichever sector ends up paying for the programme, the preceding analysis has demonstrated that society in general will benefit from the extensive control of the weed on the New South Wales tablelands.

### 5.3 A Qualification

The economic importance of a weed can be established through measurement of the change in net social benefits either caused by its presence (probable loss) or resulting from its control (probable gain). The method outlined above is appropriate for other weed and pest situations. The main data requirements relate to the area and distribution, potential rate of spread, impact on production, costs of control, and knowledge of the market conditions facing the product (or products) in question.

There are recognized problems associated with the application of the social benefit model which incorporates the concept of economic surplus to the analysis of practical agricultural problems. These problems largely concern the nature of the supply shift assumed (Lindner and Jarrett 1978) and the specification of the elasticity conditions for the relevant commodities. However, such problems are not seen as being over restrictive, particularly in view of the many contributions to this area which have appeared in recent years. The social benefit model is imperfect but the experience of its use (in the literature) suggests that it is workable if applied and interpreted carefully.

As noted by Currie *et al.* (1971, p. 791) ". . . while it is easy to raise objections to the use of the concept of economic surplus for providing answers to policy formulation, it is difficult to find any workable alternative".

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