The economic impact of weeds in Australian agriculture

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Summary Weeds have a wide variety of impacts on society, the environment and the economy. Some of the economic impacts are benefits but most are costs. Combellack (1987) valued the economic cost of weeds in 1981–82 to be $2096m. New methods of weed control and new techniques of farm management have since been developed, and new weeds have invaded. Therefore, the current cost of weed impacts cannot be readily compared to those of 1981–82. This paper attempts to estimate the economic costs of weeds in agriculture across Australia. But further, it offers an economic framework to help consider the problems that weeds create, and the generation and use of information to resolve those problems. A stochastic simulation model was developed to estimate the economic impact of weeds and to particularly account for variability in the cost estimates. The total annual economic loss to Australian agriculture ranged from $3400m to $4400m, with a mean loss of $3900m.
Keywords Loss, expenditure, economic surplus, weed cost, simulation.

INTRODUCTION

The introduction of a plant to a nation or region has provided many benefits to societies over the centuries. The introductions have supplied food, shelter, medicines and aesthetic enjoyment. But these benefits have often been accompanied by costs, particularly when the plant invades agricultural and natural ecosystems beyond its intended area. These invasions have many adverse impacts on agriculture, the environment, society and the economy, and these plants are considered to be weeds.

The costs of given weeds in particular areas have been estimated by a number of studies, but only Combellack (1987) has attempted to estimate the nationwide impact of weeds in general. Combellack valued the economic cost of weeds in 1981–82 to be $2096m. New methods of weed control and new techniques of farm management have since been developed, and new weeds have invaded. Therefore, the current cost of weed impacts cannot readily be compared with those of 1981–82. The nationwide impact needs to be re-estimated to provide a more recent benchmark that reflects current costs, prices and technologies, and the current distribution of impacts within the community. A current estimate would provide useful information to raise public awareness, influence broad public programs, and help to define problem areas and to formulate policies.

The broad goal of this paper is to estimate the value of the current economic impact of weeds for agricultural industries across Australia. This paper presents one component of a broader economic analysis of weeds that also considered the problem in environmental systems and public lands (Sinden *et al*. 2004).

MATERIALS AND METHODS

The measurement framework A common approach to the estimation of impacts is to determine only the direct cost of weed control, that is the cost of herbicide plus the labour and equipment to apply it. These costs are relevant but they are only part of the impact of weeds. The opportunity costs are also important, and these are the losses in production and losses in value of output due to a weed invasion. The framework of Figure 1 incorporates both the expenditure on weed control (E) and the loss in production (L), and provides a general way to think about the problems of weeds.

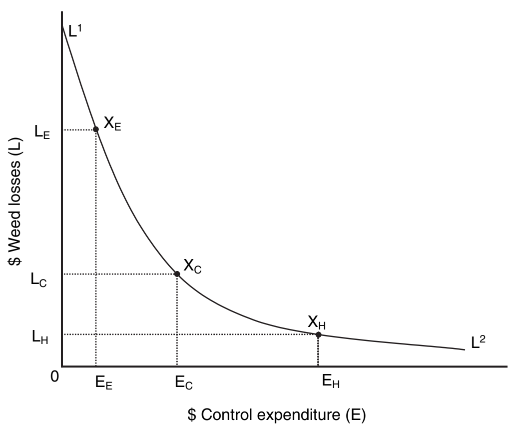

Figure 1. A framework to estimate the impact of weeds.

The curve L^1L^2 is a 'loss-expenditure frontier' that shows the lowest weed-related losses for each level of control cost for a given weed in a given situation (McInerney 1996). Without any control, losses would be at the maximum of L^1 at one end of the frontier. As control expenditure increases from 0 to E_H and beyond, losses decline but at a diminishing rate. With the maximum possible control, losses would be at their minimum level but would still be positive.

Horticulture typically involves high control expenditures per hectare but low production losses so is depicted at position X_H, whereas livestock and grazing activities typically involve low control costs per hectare but high production losses (X_E). Crops may be depicted in the middle of the frontier (X_C) with substantial control costs and substantial losses.

Expenditures and losses are both impacts and so both must be estimated and then aggregated. The total cost of the weed impact (*C*) is therefore defined by the identity:

$$C = L + E \qquad (1)$$

Weed management can be thought of as a choice between levels of *L* and *E*. The weed impact (*C*) is perhaps best measured as a loss in economic welfare. This welfare approach measures the effects of weeds upon producers and consumers within an industry, and includes the direct and indirect financial costs within the calculations. The approach is applied by aggregating weed impacts for various weed functional groups in industry-focused estimates of economic surplus.

An introduction to the economic surplus concept is given in Figure 2 which depicts the supply function (*S*) of an industry, such as wheat. The supply function is the amount of output that producers would supply at various prices and so can be interpreted as the cost of production. The presence of weeds has two impacts upon a commodity such as wheat.

(a) Variable costs of production are increased because of the use of various herbicides and increased tillage to control weeds. This increase in the cost per unit of output leads to an upward shift in the supply function, from point *a* to point *b* for a given quantity Q_X. This can be termed the *E* or expenditure effect.

(b) The competitive and allelopathic effects of weeds lead to a yield loss. There is a lower level of wheat output for a given cost of production. This is represented by a leftward shift in the supply function, from point *a* to point *c* for a given cost of production P_X. This can be termed the *L* or loss effect.

As noted in equation (1), the effects are additive and the total impact of the weed is measured as (*C*+*L*). The combined effect of weed expenditure and weed losses due to weeds is to shift the supply function from $S_{\text{no weed}}$ to $S_{\text{with weed}}$.

The shift in the supply curve to the left due to weeds reduces the welfare of both producers and consumers. Consumers lose because market supply has contracted and price increases, so they now consume less but they pay more for the privilege. Producers lose when the economic loss from the decrease in production is greater than the gain from the increased market price.

The changes in the economic surplus from weed invasions or weed control are estimated from the equations presented by Alston (1991) and discussed in Sinden *et al*. (2004).

Data collection A range of input data was required to estimate the effect of weeds on economic surplus. The key inputs were the equilibrium quantities and prices, demand elasticities, supply elasticities and the supply shift parameter for each industry due to the presence of weeds. The equilibrium quantities and prices were obtained from ABARE (2003), except for the prices for canola, sunflowers and soybeans which were not reported. These prices were derived from NSW Agriculture Farm Budget Handbooks (http://www.agric.nsw.gov.au/reader/budget). The actual quantities and prices used were derived as the average for the five-year period 1997–98 to 2001–02.

The supply and demand elasticities used for each industry were obtained from a number of sources including Jones *et al*. (2000), Myers *et al*. (1985), ABARE (1999), Brennan and Bantilan (1999), Hill *et al*. (2000) and Griffith *et al*. (2001).

The supply shift parameter has been calculated for weeds in a number of previous studies for winter crops (Jones *et al*. 2000), cotton (Walker *et al*. in press, Hoque pers. comm. 2004) and wool (Vere *et al*. 2003). As indicated by Figure 2 this parameter is one of the most important variables in determining

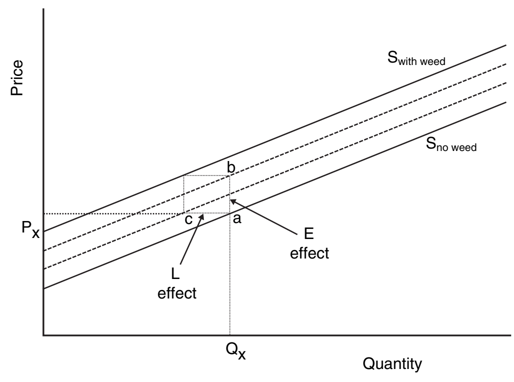

Figure 2. Change in a commodity supply function due to the expenditure (*E*) and loss (*L*) effects from a weed invasion.

the loss in economic surplus and there is considerable uncertainty surrounding its exact value. For this reason, a risk analysis was adopted whereby a triangular distribution was specified with minimum, most likely and maximum values for the supply shift (Sinden *et al*. 2004). A variety of approaches was used to estimate the supply shift for those industries with no previous estimates. For the livestock industries a grazing simulation model was used in conjunction with survey data of weeds in grazing systems (Quigley 1992 and Dellow *et al*. 2002) to estimate a range of supply shift values for various levels of weed composition. For summer oilseeds and coarse grains, values were obtained by extrapolating the values of the winter crops as a result of discussions with weed scientists regarding differences in weed burdens and crop competitiveness. The data used are presented in Sinden *et al*. (2004) for 18 agricultural industries.

RESULTS

The results of the stochastic simulation of the economic surplus loss due to weeds are given in Table 1. The economic surplus results in the table (rows 3, 6, 9, and 12 of results) are the actual results generated in the simulation. The consumer and producer surplus results are also actual simulation results and are calculated separately. Thus the economic surplus will not always be exactly equal to the sum of the consumer and producer surplus in Table 1 as each are outcomes from solution of the stochastic simulation model. The economic surplus results are the appropriate totals and so they are reported and used as the estimates of the impacts.

The mean, standard deviation, and the 5th and 95th percentiles are all reported. The latter two results give the range in the results from the simulations and are used to avoid the problems of outliers associated with the maximum and minimum values that are obtained from 10,000 iterations of the simulation model.

The changes in consumer surplus, producer surplus and total economic surplus are reported for the winter crop, summer crop and livestock industries. The results represent the scenario of ‘with’ and ‘without’ weeds and give a measure of the maximum economic gain that could be achieved if weeds were eliminated from these agricultural industries. Further results for each industry are shown in Table 2.

The main impacts due to the presence of weeds may be summarised as follows, now rounded to two significant figures.

- The mean loss in economic surplus was $3900m per annum.
- The range in this loss was from $3400m to $4400m.
- The composition of the mean loss was $1100m in winter crops, $400m in summer crops and $2400m in the livestock industries.

Table 1. Results of stochastic simulation for losses in consumer surplus (CS), producer surplus (PS) and total economic surplus (ES) due to weeds in winter crops, summer crops and livestock industries ($m).

	Mean	Standard deviation	5th percentile	95th percentile
Winter crops				
– CS	62	5	54	70
– PS	1061	100	894	1227
– ES	1122	105	949	1296
Summer crops				
– CS	59	5	51	67
– PS	337	29	288	386
– ES	396	34	339	453
Livestock				
– CS	609	71	492	728
– PS	1800	215	1441	2153
– ES	2409	270	1962	2856
Total				
– CS	729	72	612	850
– PS	3197	241	2793	3597
– ES	3927	294	3442	4420

Table 2. Loss in mean consumer surplus, producer surplus and economic surplus for individual agricultural industries ($m).

Commodity	Consumer surplus	Producer surplus	Economic surplus
Wheat	27.91	688.92	716.82
Oats	1.39	15.34	16.73
Barley	13.76	151.37	165.13
Canola	8.92	98.08	107.00
Lupins	5.09	56.04	61.13
Field peas	2.23	24.57	26.80
Chickpeas	2.37	26.04	28.41
Sorghum	3.73	41.04	44.77
Maize	0.92	10.08	10.99
Sunflowers	0.71	7.85	8.56
Soybeans	1.82	20.07	21.90
Cotton	12.28	18.01	30.30
Rice	6.28	38.38	44.66
Sugar	32.98	201.57	234.56
Dairy	177.69	471.75	649.44
Wool	230.17	358.04	588.20
Lambs/mutton	140.63	142.67	283.30
Beef/veal	58.87	824.12	882.99

- The majority of this loss was borne by producers ($3200m loss in producer surplus or 81%) rather than consumers ($700m loss in consumer surplus or 19%).

DISCUSSION

This paper has presented a framework for valuing the economic impact of weeds in Australian agricultural systems. This involves disaggregating the impact into weed losses (*L*) and weed expenditure (*E*) so as to obtain the total weed cost (*C*). Such a framework explicitly recognises that weed losses can often only be reduced by increasing expenditure on weed control. The maximum benefit from weed control involves a choice between control and loss. If the existing weed impact of an industry is the position X_E in Figure 1, where loss = L_E and control cost = E_E, the total cost is $C_E = (L_E + E_E)$.

If the best (i.e. least cost) combination of control and loss is X_C, the total cost is now $C_C = (L_C + E_C)$.

The avoidable cost, which is the maximum benefit from weed control, is equal to $(C_E - C_C)$. Therefore, the framework presented is valuable from the perspective of measuring the potential industry benefits that can be derived from weed management research.

The loss-expenditure framework was combined with the concepts of economic surplus analysis to derive the economic costs of weeds for a number of agricultural industries. Using a stochastic simulation, the annual loss in economic surplus due to weeds ranged from $3400m to $4400m, with a mean of $3900m. These values provide a baseline from which to measure the benefits from weed management research.

We have reported the results as a range of estimates because it is impossible to have confidence in an estimate at a single point in time. Clearly this range demonstrates that weeds are a significant economic problem of land use and resource management, if not the major problem, at the present time. Consequently, weed control generates substantial benefits on both private and public land, and research into weed management enhances those benefits.

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