DOES EXTENSION PAY? A CASE STUDY LOOKING AT THE ADOPTION OF LUPINS IN WESTERN AUSTRALIA.

Sally P. Marsh, David J. Pannell and Robert K. Lindner*

There is little empirical evidence available about the net economic benefits of agricultural extension. In this study we examine regional differences in the adoption of lupins in Western Australia, in orde. to estimate the influence of different levels of extension on the pattern of adoption. Differences in the starting time, rate and ceiling level of adoption for 40 shires were analysed using multi-variate regression analysis. The results suggest that both public and private extension activities influenced the start time of the adoption process for lupins, but not the rate or final ceiling level of adoption. These were largely influenced by variables directly related to profitability. Economic benefits of extension, as quantified by the statistical analysis, were combined with costs of extension estimated from public sector records and surveys of private sector extension agents and used to estimate the net present value of extension investments by the public and private sectors in the study area.

1. INTRODUCTION

The adoption of innovations, when the benefits of research and accompanying innovation are realised, is recognised as the last stage in the process of technical change. The private or public funds used to sponsor research, and the accompanying generation of innovations, is an unrealised investment until the innovation is adopted. This fact, and the crucial role of adoption in determining the rate of technical progress, has meant that researchers working in a range of diverse fields have been interested in determining the factors that affect the adoption and diffusion of innovations.

The focus of much of the literature has been on a debate between economists and sociologists, who have claimed varying degrees of importance on the influence of economic and sociological factors on the adoption process. This debate stems back to the classic exchanges between Griliches (1960) and Havens and Rogers (1961). The importance of relative profitability in influencing adoption is now widely accepted (Ruttan, 1977; Lindner, 1987; Jansen, 1992; Feder and Umali, 1993), but the importance that can be ascribed to individual adopter characteristics is still a disputed issue (Rogers, 1983; Feder *et al.*, 1985; Lindner, 1987).

The effect of extension on adoption has also been a subject of interest. Around the world, considerable funds are invested by governments, aid bodies and agribusiness in

* Marsh is M.Sc. student, Agricultural and Resource Economics, University of Western Australia.
Pannell is Senior Lecturer, Agricultural and Resource Economics, University of Western Australia.
Li:dner is Executive Dean, Faculty of Agriculture, University of Western Australia.
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extension. For example, Huffman and Evenson (1993) and Knutsen and Outlaw (1994) estimate that in excess of $1000 million is spent annually on agricultural extension by Government agencies in the U.S. Maalouff *et al.* (1991) make an estimate of $6 billion a year (and 600,000 extension workers) spent on servicing the extension needs of U.S. farmers in 1991. The involvement of the World Bank in funding Green World technology in developing countries has resulted in studies which attempt to directly evaluate the effectiveness of extension services to farmers in these countries (Feder *et al.*, 1987; Polson and Spencer, 1991; Hussain *et al.*, 1994).

There is considerable evidence suggesting that the returns to research investments are high (Evenson *et al.*, 1979; Edwards and Freebairn, 1981; Huffman and Evenson, 1993). There is, however, less consensus on the size of returns to extension investments. Those studies that have been conducted (Huffman, 1978; Feder *et al.*, 1987) have yielded equivocal results, with internal rates of return estimated in the range zero to as high as 110%. A review by Evenson and Kislev (1975) suggested that overall returns from extension are approximately the same as those from research, while Huffman (1978) concluded that past studies showed that returns to extension investments were "*modest, or better*". A more recent study by Huffman and Evenson (1993) estimated rates of return to public extension investments in the U.S. between 1950 and 1982 at 20 percent overall, ranging from 40 percent in the crop sector to negative returns in the livestock sector. This overall rate of return was approximately half of those estimated for both public and private sector research and development.

Returns to research and extension have been measured using two different approaches. The most widely used technique is that pioneered by Griliches (1960) which involves the estimation of an agricultural production function and uses regression analysis to partition the contribution of research, thus measuring the marginal productivity of research. The second technique involves the calculation of economic surplus by estimating the long-run supply curve, and uses cost-benefit analysis to measure the average productivity of research.

Research which has focussed on the economic benefits of extension suffers from methodological flaws, the most serious of which has been an inability to disaggregate the effects of extension from contributions to productivity from other sources, notably from research and human capital (Huffman, 1978; Norton *et al.*, 1984; Huffman and Evenson, 1993). Additionally, there are difficulties associated with assessing both extension expenditure, and output resulting from those expenditures. As concluded by Baxter *et al.* (1989):

> *"No government or public extension service is readily able to indicate the total recurrent and capital cost of its extension operations. Even when approximations can be made, there remain legitimate questions about which parts of an agricultural service system as a whole, and its administration, constitute 'extension' expenditure. Without such information, it is difficult to justify unequivocally different levels of investment in extension or to present definitive statements on the cost of one extension approach in comparison to others, even assuming that the different objectives of, and approaches to, extension would allow valid comparisons."* (p 51)

The rates of return to investments in extension activities in Australia have not been documented, and there have been few studies elsewhere. Despite this, there is a world-wide trend towards the privatisation of agricultural extension services (Rivera and Gustafson, 1991), exemplified locally by recent developments in New Zealand and Tasmania, and, to a lesser extent, in the other Australian states. This trend appears related to factors such as the declining relative importance of agriculture in the economy, budget pressures on governments, and privatisation policies for services seen to have relatively high "private-good" characteristics.

The re-introduction of lupins into Western Australian farming systems in 1979 and their subsequent adoption provided an ideal framework for a temporal diffusion study designed to investigate the influence of extension activities on the adoption process. The research and development work associated with this new crop was largely confined to W.A.[1], which meant that the effect of external influences could be considered minimal . Information about the productive capabilities of lupins, their role in the Western Australian farming system, and management techniques required to grow them successfully were extended vigorously by AgricultureWA[2], and the new crop was adopted rapidly by farmers in the 1980s. This comparatively recent and concise history has meant that it has been possible to get access to reasonable shire-level records that cover the work associated with the development, associated basic and applied research, and extension of this crop.

Lupins have proven to be an innovation that is highly profitable and compatible with Western Australian farming systems. Furthermore, the diffusion process was suspected to be largely complete for a considerable part of the State, preventing the type of methodology problems associated with data from incomplete diffusion patterns that are discussed by Lindner (1987). The highly profitable nature of the new legume crop and its rapid adoption meant that the debate regarding the role of extension for innovations perceived as "unprofitable" (for example, conservation practices) raised by Pampel and van Els (1977) and Napier *et al.* (1984) is not an issue for this case.

In this study the returns to extension were measured using an economic surplus type approach, looking at the differences in production returns over time "with" and "without" extension. Where extension effort was found by the multivariate regression analyses to have any effect on start time, rate or ceiling level of adoption, the relevant extension variables were omitted from the model to give an estimate of the "without" extension scenario. Shortening of any of the time lags associated with the adoption process attributable to extension effort was seen as having discounting benefits. This approach has been used *ex-ante* (Edwards and Freebairn, 1981; Norton *et al.*, 1987; Gross *et al.*, 1991) to measure the benefits of shortening the adoption process, but the authors are unaware of any other similar *ex-post* analysis.

Costs associated with both public and private extension effort have been estimated. In this respect this study attempts to address one of the major biases present in most other studies (Huffman, 1978) which measure returns to extension without accounting for private extension input.

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[1] A history of the development of the sweet white-flowering lupin is provided by Gladstones (1982).
[2] Formerly known as the Western Australian Department of Agriculture (DAWA).

2. BACKGROUND ON LUPINS IN WESTERN AUSTRALIA

Few new industries have been adopted so rapidly and successfully as the lupin industry in Western Australia. The area planted to sweet narrow-leafed lupins (*Lupinus angustifolius*) in W.A. has grown from less than 100,000 hectares in 1980 to a peak of 877,000 hectares in 1987, and plantings in 1992 of 822,000 hectares. The first sweet white-flowering lupin (cultivar Uniwhite) was released in 1967 and promoted as a legume crop especially suitable for sandplain soils in the heavier rainfall areas of the northern wheatbelt. By 1973 the area planted to lupins was 120,000 hectares, but a combination of poor management practices by farmers and droughts in 1976 and 1977 saw lupins lose favour. By 1978 the area planted had fallen to 40,000 hectares. In 1979, a higher yielding cultivar (Illyarrie) was released and a major extension effort commenced by AgricultureWA's Geraldton district office in the northern wheatbelt area. This extension effort was credited with contributing to the rejuvenation of the lupin industry during the 1980s (Nelson, 1987).

In 1981 AgricultureWA commenced trials and extension activities in the Merredin region to demonstrate that lupins could play a valuable role in farming systems in drier areas of the wheatbelt. The remainder of the 1980s saw the rapid adoption of lupins throughout the agricultural area of W.A., the release of further improved varieties, the development of overseas markets for the new crop, and considerable trial and extension effort by both the public and private sectors put into the developing lupin industry.

The uptake of the new crop varied widely between regions. Figure 1 shows the percentage of farmers in the shire growing lupins over time for five shires in the W.A. wheatbelt, from Chapman Valley in the north, then progressively southeast through Wongan-Ballidu, Wyalkatchem, Corrigin and Lake Grace. All the shires illustrated, except Lake Grace, appear to have gone through a complete diffusion process, and reached a ceiling level of adoption. This is the case for the majority of the 43 shires in

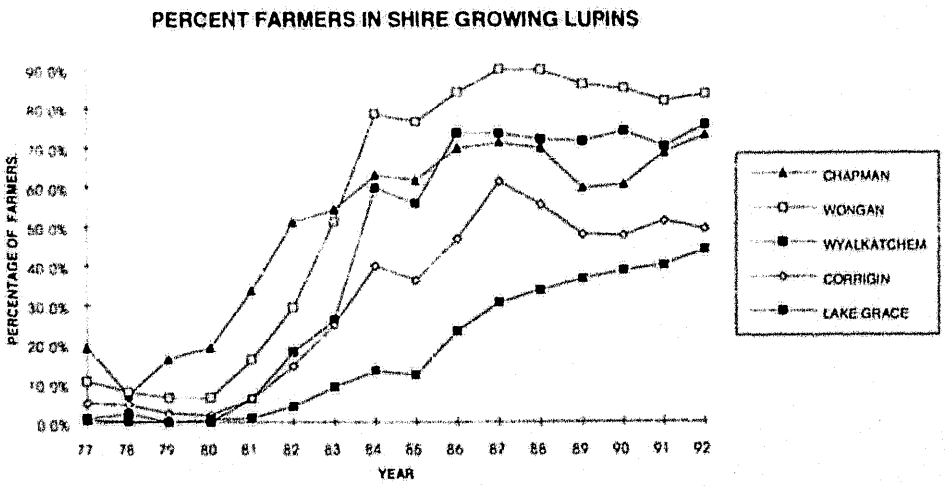

Figure 1

the study. The shires shown in Figure 1 illustrate differences in the adoption of lupins that can be seen in different areas of the state. For each of the five shires there are differing times when the adoption process commenced, differing ceiling levels of adoption reached and differing rates of adoption to reach the ceiling. Obviously, a great number of factors influence these differences, and one of the initial aims of this study was to attempt to segregate and quantify the effect of extension activities on the adoption process.

3. IMPACT OF EXTENSION ON ADOPTION OF LUPINS

A methodology similar to that pioneered by Griliches (1957) was used to estimate start times, rates and ceiling levels of adoption in 43 shires of the northern and central wheatbelt, covering an area serviced by the AgricultureWA advisory districts of Geraldton, Three Springs, Moora, Northam, Merredin and Lake Grace. These shires represent most of the major lupin growing areas in the State, although some southern shires not included in the study (for example, Esperance and Ravensthorpe) have lupin enterprises of growing importance. These estimates were then used as dependent variables in multivariate regression analyses, in an attempt to determine factors influencing the diffusion process.

Data was collated on an individual shire basis. By examining adoption behaviour at the shire level (rather then the usual national or State level) it was hoped that this greater than usual detail would better allow detection of the impacts of extension. A considerable number of possible dependent variables were investigated (Marsh *et al.*, 1995), in the following general areas:

- estimates of percentages of soils suitable for lupins in the shire,
- measures of climatic variability,
- measures pertaining to lupin yields,
- measures of scale,
- variables to capture the extent of cropping intensity in the shire,
- variables to capture farmer experience with growing lupins,
- measures of distance from information sources,
- measures of Agriculture WA extension activities, and
- measures of private sector extension activity.

As reported by Marsh *et al.* (1995), results from the multivariate regression analyses suggest that there is evidence that extension did affect the start time of the adoption of lupins in the study area. Approximately 70 percent of the variability in start time was accounted for by four variables, two of which, *Field Days 1980* and *Adviser Distance 1979*, are measures of extension activity. A third variable, *Lupin Farmers 1979*, describes the percentage of farmers with previous experience of the technology. The remaining variable, *Crop %*, is a measure of the profitability of cropping in the area compared to alternative grazing enterprises. All variables had the expected sign, and diagnostic tests indicated no problem with the regression. The addition of three dummy variables, namely *Geraldton*, *Merredin* and *Consultant 1*, which take account of major AgricultureWA extension efforts in the Geraldton and Merredin areas, and the activities of a private consultant, result in the model describing over 80 percent of the variability in start time. The significance of these variables suggests that concerted extension activity from either the public or private sector, as occurred in these areas, did influence adoption start times. Regression results and a definition of the variables listed here are given in Appendix 1.

Other results (as yet unpublished) show that extension was not a factor influencing ceiling levels of adoption of lupins. Significant variables in this analysis were those describing yields, rainfall and percentage of the shire cropped. These are all variables which measure the production environment, and impact on profitability. These findings are supported by previous research. Likewise, the evidence from the regression analysis of adoption rate also points to the overwhelming influence of profitability factors on the rate of adoption of lupins. There is some evidence, albeit slight, to suggest that the run to the first peak of adoption was positively influenced by the specific extension efforts of the Geraldton and Merredin AgricultureWA district offices. Similarly, there is some evidence, again slight, to support the assertion that AgricultureWA field days and seminars have been influential in positively affecting the rate at which shires reach maximum percentages of farmers growing lupins. However, any influence of extension on rate of adoption of lupins in different areas is too low to be clearly identified by our analysis.

4. METHODOLOGY FOR COST-BENEFIT ANALYSIS

4.1 Estimates of benefits attributable to lupin extension in the study area

Using the coefficients from Model 1 (see Appendix 1), three calculations were made. The function was solved for Y (the start time) using the actual values of the coefficients, and then with the coefficients for extension variables (*Field Days 1980*, *Geraldton*, *Merredin*, and *Consultant 1*) set to zero, and the difference in start time calculated. The coefficient for *Adviser Distance 1979* was not set to zero for this initial calculation as it could not just be simply omitted in combination with the other extension variables to give any interpretable result. To calculate the impact of the *Adviser Distance 1979* variable on the start time, the value of this variable for each shire was adjusted to the value that it would be if there was only 1 adviser in the district office. The rationale for this approach was that with only one adviser it could be hypothesised that there would be effectively no, or minimal, extension activities undertaken. This adjusted variable value (equal to the distance from the AgricultureWA district office) was then used in the solving of the function using the calculated coefficient for *Adviser Distance 1979* and with coefficients of other extension variables set to zero as before. Differences in start times were again calculated. This data is all presented in Table 1.

The first column in Table 1 gives the parameter estimate of start time. The second column gives the estimate of start time when coefficients from Model 1 are used to solve the function for Y (the start time). This model had a R-bar squared of 0.80. Columns 3 and 4 give the estimated start time from the regression when the coefficients on the extension variables (*Field days 1980*, *Geraldton*, *Merredin* and *Consultant 1*) were set to zero, and the difference in years from the initial estimate, respectively. The effect of removing the extension variables has resulted in a delay in the start time ranging from zero years in some shires, up to 2.13 years for two shires.

TABLE 1

EFFECT OF EXTENSION VARIABLES ON START TIMES

SHIRE	START YEAR		EFFECT OF EXTENSION VARIABLES			
	Parameter est	Model 1 est	W/o extension	Diff	W/o ext & advdistance	Diff
Geraldton District Office:						
1. Chap Valley	78.70	79.06	81.20	2.13	81.73	2.66
2. Greenough	79.01	79.30	81.21	1.91	81.61	2.31
3. Irwin	79.04	78.79	80.47	1.68	81.60	2.81
4. Mingenew	78.98	78.99	80.67	1.68	82.00	3.01
5. Morawa	81.52	81.47	81.70	0.23	83.55	2.08
6. Mullewa	80.25	80.80	81.25	0.45	82.38	1.58
7. Northampton	79.04	79.25	81.38	2.13	82.18	2.93
Lake Grace District Office:						
8. Kondinin	81.49	81.99	81.99	0.00	82.70	0.71
9. Kulin	81.67	81.87	81.87	0.00	82.33	0.46
10. Lake Grace	82.08	81.63	81.63	0.00	81.98	0.35
Merredin District Office:						
11. Bruce Rock	81.31	81.11	81.55	0.44	82.26	1.15
12. Corrigin	81.20	80.99	81.66	0.66	82.78	1.78
13. Kellerberrin	81.34	81.08	81.52	0.44	82.05	0.97
14. Koorda	81.26	81.48	81.92	0.44	83.45	1.97
15. Merredin	80.53	80.92	81.36	0.44	81.60	0.68
16. Mt Marshall	81.30	81.28	81.71	0.44	82.89	1.62
17. Mukinbudin	81.26	81.13	81.57	0.44	82.45	1.32
18. Narembeen	81.44	81.21	81.65	0.44	82.47	1.26
19. Nungarin	81.27	80.89	81.33	0.44	81.80	0.91
20. Trayning	81.08	81.03	81.47	0.44	82.18	1.15
21. Westonia	80.71	80.92	81.36	0.44	81.95	1.03
22. Yilgarn	80.93	81.22	81.66	0.44	82.55	1.32
Moora District Office:						
23. Dalwallinu	81.01	81.28	81.28	0.00	82.28	0.99
24. Dandaragan	80.71	80.80	81.03	0.23	81.76	0.95
25. Moora	80.76	80.73	81.07	0.34	81.40	0.67
26. Vic Plains	80.72	81.21	81.32	0.11	82.11	0.91
27. Wongan	80.86	81.25	81.25	0.00	82.31	1.06
Northam District Office:						
28. Beverley	82.03	81.73	81.73	0.00	82.53	0.80
29. Cunderdin	80.62	80.41	81.31	0.90	81.97	1.56
30. Dowerin	80.59	80.80	81.48	0.68	82.47	1.67
31. Goomalling	81.33	81.56	81.57	0.01	82.23	0.67
32. Northam	81.63	81.14	81.37	0.23	81.57	0.42
33. Quairading	81.54	81.70	81.70	0.00	82.76	1.06
34. Tammin	80.73	81.22	81.66	0.44	82.72	1.50
35. Wyalkatchem	81.13	81.01	81.45	0.44	82.64	1.63
36. York	81.97	81.10	81.32	0.23	81.72	0.62
Three Springs District Office:						
37. Carnamah	80.73	81.16	81.38	0.23	81.65	0.49
38. Coorow	81.21	81.82	81.27	0.45	81.80	0.98
39. Perenjori	82.21	81.69	81.69	0.00	82.22	0.53
40. Three Springs	79.85	80.37	80.82	0.45	80.95	0.58

Similarly, Columns 5 and 6 report start times and differences when extension variables are set to zero as before, and the value of *Adviser Distance 1979* for each shire is calculated assuming only one adviser. Delays in start time are now more pronounced, ranging from 0.35 to 3.01 years.

Other variables influencing this regression other than extension variables are *Crop %* (the percentage of farm land in the shire that is cropped) and *Lupin Farmers 1978* (the percentage of farmers in the shire growing lupins in 1978). *Crop %* is a measure of relative profitability, in the sense that it quantifies the extent of all cropping enterprises in each shire. *Lupin Farmers 1978*, however, is a variable that captures farmer experience with growing lupins in the 1970s. This variable very probably reflects to some extent, the location and results of early lupin extension. The differences in start time calculated could conceivably underestimate the role played by extension in bringing forward the start time of the adoption process.

To assess the dollar benefits associated with earlier (or delayed with no extension) start times, the delayed start times were translated into delays on the areas planted to lupins in different shires, equivalent to the delay in each shire. The areas planted to lupins, after adjustment according to the delay in starting times, were calculated for each year for each shire for the years 1979 to 1992 inclusive. The total area planted to lupins in the study area, and the adjusted area after accounting for the delayed start in the absence of extension, along with some examples from individual shires, are tabulated in Appendix 2. These areas were then given dollar values.

Establishing a dollar value for a hectare of lupins presented some difficulties. The value of lupins cannot simply be estimated by returns from the harvested grain, as grown in rotation with cereals, they give substantial benefit to the overall cropping system (Nelson, 1993). Factors such as the disease break for cereals, nitrogen fixation by lupins and the value of stubble and lupin grain for stock feed must be considered, or the profitability of lupins will be substantially underestimated. Accordingly, the benefits from lupin adoption need to be estimated at a farm level rather than an enterprise or rotation level.

The MIDAS model (Model of an Integrated Dryland Agricultural System) provides a means of assessing the impact of single enterprises on whole farm profitability on W.A. eastern wheatbelt farms (Kingwell and Pannell, 1987). A number of estimates of the contribution made by lupins to overall farm profitability, ranging from $27 to over $60 per hectare, have been made using this model (Ewing et al., 1987; Pannell and Bathgate, 1991; Kingwell, 1991). Three values of dollar benefit per hectare ($45, $30 and $15) were used in the analysis and these were assumed constant over time. Given the nature of the index of farm prices to farm costs, this assumption is not unreasonable.

A number of different scenarios were used to estimate the benefits of lupin extension in the study area. Benefits were estimated over the period 1979 to 1989. This start year corresponds with the release of the new variety, and by 1988 the "without" extension situation had caught up (in terms of hectares planted) with actual lupin plantings. Initially the two delayed estimates of start time were used to calculate benefits for the three different values for a hectare of lupins, at two different interest rates, giving 12 possible benefit estimates.

These estimates assume that the full benefit from a hectare of lupins was immediately available to farmers. Another set of estimates hypothesised an effect of extension on the time when farmers achieved full benefit from a hectare of lupins. Unmeasurable by the methodology used by us to investigate adoption rates is the role of extension in educating farmers about the production potential of the new crop. Extension could have played a role in helping farmers achieve the production capability of the new crop. Taped interviews made during the course of this study with extension personnel working in the Merredin area emphasise this point. They mention such things as working closely with farmers who were growing lupins for the first time to assess management techniques, and reasons for crop failures and successes.

Estimates were done with the full benefits from a hectare of lupins not being achieved until 1983. Average state-wide lupin yields reached approximately 1 tonne/ha in this year. In 1979 average state yields were only approximately 0.5 tonne/ha. For these estimates, the benefit in 1979 was assumed to be half the full benefit, and this increased linearly over the next three years, reaching the full benefit in 1983. Another set of estimates assume that the full benefit from a hectare of lupins was not achieved until 1989. For these estimates, the benefit in 1979 was assumed to be half the full benefit, and this increased linearly over the next ten years, reaching the full benefit in 1989.

4.2 Estimates of public sector costs associated with lupin extension in the study area

AgricultureWA was the only major public sector player involved in the extension of lupins. As discussed in Section 1, there are inherent difficulties associated with costing overall, let alone single enterprise, extension effort. This caveat aside, attempting to get an understanding of AgricultureWA spending by enterprise and region in the 1980s is in itself a daunting task. Total AgricultureWA spending, extension spending and R & D spending was obtained from AgricultureWA Annual Reports. These figures are listed in Appendix 3. Records were obtained for total spending by region for the years 1985/86 to 1991/92. Estimates for spending on extension in the study area were then made in three categories in the following manner, and these are presented in Table 2.

i) Estimate of regional spending (excluding salaries)

The breakdown of figures for regional spending obtained for the years 1985/86 to 1989/90 were used to obtain values for regional office costs (minus salaries) in the study area, and then a proportion of this was allocated to lupins. Dollars spent by northern area district offices, northern area research stations, central area district offices and central area research stations, were each expressed as a percentage of total AgricultureWA spending for these five years. The northern area included Geraldton, Three Springs and Moora district offices, and the central area comprised the Lake Grace, Merredin and Northam district offices. The average of these percentages was then used to obtain dollar values for years other than 1985/86 to 1989/90. The proportion allocated to lupins was estimated in the following manner. For each year

Table 2

Estimates of AgricultureWA's spending (in actual dollars) and total time spent by private consultants (and associated costs in 1992/93 dollars) on lupin extension in the study area

	AgricultureWA Costs				Private consultant time and costs	
Year	Reg est actual $	Ext est actual $	R&D est actual $	Total est actual $	Est FTE	Cost 1992/93 $
1978	3715	0	14780	18495	0.55	61662
1979	8857	20245	22943	52045	0.55	61662
1980	28193	28464	66612	123268	0.81	90811
1981	52031	34664	130801	217496	1.01	113234
1982	113166	139327	272637	525130	1.01	113234
1983	127819	293213	389791	810823	1.01	113234
1984	181996	172605	370354	724955	1.01	113234
1985	213887	298041	477571	989499	1.01	113234
1986	281784	684256	655850	1621890	1.16	130351
1987	210943	725573	664071	1600587	1.36	152473
1988	378064	699541	958541	2036147	1.41	158079
1989	436095	727484	1134344	2297922	1.58	177138
1990	410909	770493	1172283	2353685	1.58	177138
1991	504127	1178320	1581004	3263451	1.58	177138
1992	274288	792792	835878	1902958	1.58	177138
1993	288670	821663	821663	1931995	1.58	177138

the number of lupin trials[3] in the four areas listed above was expressed as a percentage of the total number of trials conducted in these areas. These percentages were then used as estimates of the percentage of district office effort going towards lupin extension, and dollar values were thus obtained from the regional office spending values already obtained. These figures are listed in column 2 of Table 2.

ii) Estimate of district office extension

This calculation was intended to account for the regional salary component that should be allocated to lupin extension. It was estimated as a percentage of AgricultureWA's total estimated expenditure on extension. For each year the number of lupin trials conducted by the district offices in the study area (but not including trials conducted on research stations) was expressed as a percentage of the total number of AgricultureWA trials. These percentages were then used to obtain dollar values from total extension spending, and these are listed in column 3 of Table 2.

[3] Lupin trials did not include lupin Crop Variety Trials (CVTs), but the figure for total trials did include all CVTs. CVTs are largely conducted by research personnel from AgricultureWA's head office, and were considered to be more research than extension orientated. Trial numbers were obtained from hardcopy records and AgricultureWA's Research Information System (RIS).

iii) Estimate of the extension component of applied lupin research
Much lupin trial work is applied rather than basic research and contains a considerable extension component. This calculation was intended to account for the extension component of trial work conducted by research stations and district offices, where personnel involved include research personnel based in AgricultureWA's head office. Their salaries would comprise part of the R & D component of AgricultureWA's expenditure. For each year the number of lupin trials conducted by the district offices and research stations in the study area was expressed as a percentage of total AgricultureWA trials. This percentage was then used to obtain dollar values from total R & D spending, 30 percent of which was then deemed to be extension expenditure. Use of this percentage was based on AgricultureWA's "rule of thumb" for breaking down expenditure, which allocates 50 percent to R & D, 30 percent to extension and 20 percent to regulatory activities.

4.3 Estimates of private sector costs for lupin extension in the study area

Private sector costs associated with lupin extension in the 1980s are very minimal. This would no longer be expected to be the case. Our experiences in talking with private sector personnel persuades us that the inability of public bodies to isolate extension costs commented on by Baxter *et al.* (1989) applies also to any estimates of private sector extension costs. Private sector costs were ascertained in three areas.

i) Private farm management consultants
A number of private farm management consultants were known to be active in the study area. To investigate their involvement with extending the new lupin technologies, a one page mail survey was conducted of private consultants working in the study area. Estimates for the time spent by private consultants on lupin extension were made from these survey results. From the information on when they had commenced to consult in the study area and their nominated percentages of time spent extending information on lupins, an estimate of the number of "full-time consultant equivalents" was calculated for each year. The average percentage time spent on lupin extension was used for those consultants who did not nominate a percentage.

To produce a value for a private consultant FTE, income information from a survey of AAAC consultants in W.A. conducted by Bedbrook (1995) were used. He reported that, on average, these consultants charged $97 per hour for 25 chargeable hours per week. Assuming that consultants work for 48 weeks per year, this gives a gross annual income of $116,400 in 1994/95. Discounted back (using the CPI for Perth), this gives a gross annual income of $112,113 in 1992/93. This figure, along with the estimates of consultant FTEs spent on lupin extension, was then used to calculate the contribution to lupin extension made by private consultants. These values are given in Table 2.

ii) Agribusiness
A number of agribusiness firms have invested in research and extension in lupin related areas, although extension investments can be considered minimal during the 1980s. Cost estimates for agribusiness and marketing bodies are presented as totals in Table 4.

In the early 1980s CSBP & Farmers Ltd. was the only company involved in supplying fertiliser to farmers. They conduct fertiliser trials and provide fertiliser recommendations to farmers based on the results of soil and plant tests. They also have Field Officers (resident at various rural locations) and agronomists, and produce a a number of publications. Estimates for the investment in extension made by CSBP are derived from figures obtained from a personal interview with a Company representative. For the purposes of this study, the costs associated with product development are assumed to be research and development, rather than extension related, investments. Of other costs, an arbitrary 50:50 split has been made between R & D and extension investment. CSBP's figure of 10% of overall time (based on soil and plant test requirements) has been used to attribute the time spent by personnel on lupin extension.

The development of minimum tillage and weed control technologies for use in W.A. agricultural systems in the late 1970s/early 1980s was actively undertaken by the chemical companies involved (Rhone-Poulenc, May & Baker and ICI). It was these technologies which enabled the early sowing of lupins and adequate control of weeds in the growing crop, both factors crucial to their management for optimal yield. Despite a number of approaches, it proved very difficult to obtain information from the companies involved. Information from AgricultureWA staff based in Merredin in the early 1980s indicate that a field officer with ICI worked closely with them in setting up and monitoring trials in the Merredin area, and was used as an "expert" speaker at AgricultureWA field days and meetings in this area. Accordingly, an arbitrary estimate of 0.25 FTE was costed to lupin extension for the years 1981, 1982 and 1983.

Although the involvement of stockfirm companies in extension, through the employment of agronomists attached to the company, is now quite considerable, this is a comparatively recent development in W.A., and was not the case in the early 1980s. Both SBS Rural Iama and Rural Traders Cooperative were not active in W.A. at this time and the contribution of stockfirm companies Elders Ltd. and Wesfarmers Rural to lupin extension in specific areas in the 1980s was deemed to be minimal.

iii) Marketing Bodies

The marketing of lupins in W.A. is the sole responsibility of The Grain Pool of W.A. This semi-Government agency had the task of developing markets for an essentially new and unknown crop. To achieve this, the Grain Pool has invested, and continues to do so, a considerable amount of money into market development and research associated with the nutritive value of lupins for livestock and human foods. Having obtained markets for the new crop, the Grain Pool was then faced with the necessity of providing buyers with a continuity of supply, and became involved, both directly and through sponsorship, with extension activities to farmers.

An accurate costing of Grain Pool lupin extension activities is extremely difficult to obtain by perusal of their Annual Reports. Additional information was obtained from a personal interview with a Grain Pool representative. The main extension role undertaken in the 1980s was involvement in field days and grower seminars, and through their media releases and regular publications. From 1990 this commitment to lupin extension was increased by the Grain Pool's funding of a Specialist Lupin Extension Officer and the production of the monthly newsletter "Lupin Logic".

For the purposes of this study, the lupin extension contribution for direct grower contact by Grain Pool staff through seminars, field days and individual grower contact was said to be 5% of 5 FTE per year from 1983 to 1987, and 5% of 7 FTE per year from 1988 onwards. Additional costs were attributed to specific extension activities in the study area. A staff full-time equivalent has been costed in at $38,660. This was considered an appropriate mid-range value, equivalent to a Level 5 public service salary. This value was also used for costing agribusiness staffing contribution to extension activities. No attempt has been made to value and cost in the extension component of investments associated with the market development of lupins to potential overseas buyers. The extension that has been valued for this analysis is that more directly aimed at farmers in Western Australia.

5. RESULTS AND DISCUSSION

The estimates of benefits are given in Table 3. These benefits represent the difference between the value of the actual hectares grown and the estimated hectares grown in the absence of extension under a number of different scenarios. The three levels of "assumed impact of extension on benefit per hectare" of zero, low and high correspond to full benefits per hectare being achieved in 1979, 1983 and 1989 respectively.

Table 3

Estimates of the benefits of lupin extension in the study area (All values are expressed in 1992/93$ (millions))

		Variables used to calculate the impact of extension			
Lupin on-farm benefits	**Assumed impact of extension on benefit per ha**	**Impact of extension on adoption Estimate 1***		**Impact of extension on adoption Estimate 2#**	
		Discount rate (%)		**Discount rate (%)**	
$/ha		**5**	**10**	**5**	**10**
45	zero	$23.7	$36.5	$56.5	$84.3
	low	27.8	43.6	59.7	89.8
	high	57.8	85.7	82.4	121.3
30	zero	15.8	24.4	37.7	56.2
	low	18.5	29.1	39.8	59.9
	high	38.5	57.1	55.0	80.9
15	zero	7.9	12.2	18.8	28.1
	low	9.3	14.5	19.9	29.9
	high	19.3	28.6	27.5	40.4

* Estimated value of extension variables *Field Days 1980*, *Geraldton*, *Merredin* and *Consultant 1*.

As for Estimate 1, plus the value of the *Adviser Distance 1979* variable.

Table 4
Estimated total lupin extension costs in the study area 1979-1989 (in 1992/93 $)

	Discount Rate 5%	Discount Rate 10%
Public Sector - AgricultureWA:		
Regional costs (minus salaries)	$3,448,585	$4,664,549
Component of extension spending	6,225,276	8,259,712
Component of R & D spending	8,659502	11,683,259
Private Sector:		
Private consultants	1,336,385	1,336,385
CSBP	553,616	625,073
Grain Pool	87,423	93,331
Other	28,995	28,995
TOTAL COSTS	**$20,339,782**	**$26,691,305**

Using the methodology outlined in Section 4.2, total estimates of extension spending in the study area were obtained. These were then expressed in 1992/93 dollars using two interest rate situations - CPI for Perth plus 5 percent and CPI plus 10 percent. Costs for the extension of the lupin technology (release of the new variety Illyarrie and improved management techniques) were costed, as for benefits, over the years 1979 to 1989. Overall estimates of lupin extension costs in the study area are totalled in Table 4. Using these total costs, a benefit cost ratio was calculated for the scenarios presented in Table 3. These are presented in Table 5.

Based only on statistically estimated effects (i.e. assuming the effect of extension on on-farm benefits of lupins was zero), and using the estimate with extension variables set to zero (for *Field Days 1980*, *Geraldton*, *Merredin* and *Consultant 1*) and adjusted for *Adviser Distance 1979*, the benefit cost ratio of extension expenditure appears to be at least one. Using what we consider to be realistic values for the on-farm benefits of lupins, the benefit cost ratio is clearly greater than one. Of the significant extension variables in the regression, *Adviser Distance 1979* was the least robust (Marsh *et al.*, 1995). If the *Adviser Distance 1979* variable is used unadjusted for the benefit calculations, and we assume zero impact on benefit per hectare, the benefit cost ratio is only greater than one for the higher assumed value of on-farm benefits.

If extension also had unmeasured impacts on the on-farm benefits for the first four or ten years of the period, the benefit cost ratios are substantially higher in all cases. On balance it does appear likely that the net benefits of expenditure on lupin extension were positive.

The diffusion pattern associated with the adoption of lupins could well be considered as representing an extreme case. As outlined in Section 2, they have proved to be a very successful crop innovation, and the extension conducted by AgricultureWA was widely perceived to have been a very successful campaign. Considering this, the statistically detectable effects of extension might be considered surprisingly small. However, as discussed in Section 1, the overriding influence of economic factors on the adoption process is well established, and it is perhaps encouraging that any measurable benefit at all from extension activities, for such a profitable crop innovation, has been isolated using multi-variate regression analysis.

Table 5

Ratio of benefits to costs associated with lupin extension (1979-89) in the study area

		Variables used to calculate the impact of extension			
Lupin on-farm benefits	Assumed impact of extension on benefit per ha	Benefit:Cost Extension estimate 1* Discount rate (%)		Benefit:Cost Extension estimate 2# Discount rate (%)	
$/ha		5	10	5	10
45	zero	1.17	1.37	2.78	3.16
	low	1.37	1.63	2.94	3.36
	high	2.85	3.21	4.06	4.54
30	zero	0.78	0.91	1.86	2.10
	low	0.91	1.09	1.96	2.24
	high	1.90	2.14	2.71	3.03
15	zero	0.39	0.46	0.93	1.05
	low	0.46	0.54	0.98	1.12
	high	0.95	1.07	1.35	1.51

* Estimated value of extension variables *Field Days 1980*, *Geraldton*, *Merredin* and *Consultant 1*.

As for Estimate 1, plus the value of the *Adviser Distance 1979* variable.

The methodology used in this study does not have the capacity to capture all the benefits of extension. One of these, the likelihood of extension to have an impact on on-farm production capacity, has been investigated as a hypothesised section of the results. As discussed in Section 1, most extension evaluation fails to capture its contribution to human capital, and this study is no exception. A further key value of extension not captured by this study is its benefit to research through choice of research topics and specific research methodology. Baxter *et al.* (1989) comment on

> *"the need to acknowledge and facilitate the dual role of extension - to advise farmers on how to increase their productivity and incomes, and to learn from farmers their production conditions and priorities in order to be able to advise and guide agricultural research."* (p 5)

Estimates of the costs and benefits in this study can be expected to have accuracy limitations, as discussed in the text. Benefits have been calculated over a range of possible situations, lending credibility to our statement that on balance it does appear likely that the net benefits of expenditure on lupin extension were positive. As well as the difficulties associated with partitioning costs to regions and enterprises discussed earlier, the estimate of costs has a number of conceptual difficulties. For example, given that public extension services are already in place, how much extension effort should be costed into cost/benefit analyses?

Despite these difficulties, it does appear most likely that this is an example where extension has generated benefits in excess of costs. This is despite the fact that measured benefits were limited to changes in the start time of the diffusion curve. This effect was sufficient for a benefit cost ratio of at least one.

6. ACKNOWLEDGMENTS

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APPENDIX 1

Table 6

START TIME REGRESSION RESULTS AND VARIABLE DEFINITIONS

Regressors	Coefficient	Standard Error	T-Ratio[Prob]
Model 1: $R^2 = 0.84$	R-bar$^2 = 0.80$	Sample size=40	
Intercept	82.0215	0.45791	179.1218[000] ***
Crop %	-1.4684	0.96221	-1.5260[.137]
Lupin Farmers 1978	-3.7991	1.0925	-3.4776[.001] ***
Field Days 1980	-0.2251	0.11476	-1.9614[.059] *
Adviser Distance 1979	0.017679	0.0080027	2.2091[.034] **
Geraldton	-1.4585	0.26774	-5.4475[.000] ***
Consultant 1	-0.67502	0.30781	-2.1929[.036] **
Merredin	-0.43980	0.18019	-2.4407[.020] **

*** Significant at 1%
** Significant at 5%
* Significant at 10%

- **Crop %** — Percentage of farmland in the shire in crop, averaged for the years 1980 to 1984
- **Lupin farmers 1978** — Percentage of farmers in the shire growing lupins in 1978
- **Field Days 1980** — Cumulative meetings, seminars and field days conducted by AgricultureWA upto and including 1980
- **Adviser Distance 1979** — Ratio of the distance of the shire from the AgricultureWA district office to the numbers of advisers working in that office in 1979
- **Geraldton** — A dummy variable for shires in AgricultureWA's Geraldton advisory district (except low rainfall shires Mullewa and Morawa)
- **Consultant 1** — A dummy variable for the shires in which Consultant 1 was operating
- **Merredin** — A dummy variable for shires in AgricultureWA's Merredin advisory district (plus Tammin and Wyalkatchem)

APPENDIX 2

Table 7

ACTUAL HECTARES PLANTED TO LUPINS IN THE STUDY AREA, AND ESTIMATES OF HECTARES IN THE ABSENCE OF EXTENSION

HECTARES PLANTED TO LUPINS									
	GREENOUGH			CUNDERDIN			TOTAL		
Year	Actual	Est 1*	Est 2#	Actual	Est 1	Est 2	Actual	Est 1	Est 2
1978	1723			140			27982		
1979	3261	1703	1701	39	130	177	35803	27637	27016
1980	2910	1863	1713	97	42	95	43312	31698	27558
1981	7081	3229	2790	401	127	63	82902	51354	34346
1982	11929	3291	3018	3968	757	230	180544	109078	57941
1983	12900	7524	5803	9700	4541	1959	295400	218723	125365
1984	13900	12018	10443	17700	10499	6472	475400	390879	250886
1985	10800	12991	12602	15300	17460	13195	455300	453349	403690
1986	15800	13617	13594	21800	15949	16651	584500	536643	463798
1987	18000	11257	11750	29500	22569	18140	778900	684339	567889
1988	15400	16001	14268	25600	29110	25164	636100	673390	687965
1989	9300	17763	17326	22400	25280	27796	579800	637319	673052
1990	9622	14843	16197	20847	22245	24202	557611	589016	627347
1991	12882	9329	11170	24178	21180	21721	639017	598210	590648
1992	13740	9920	9523	27137	24474	22302	662369	629073	608741

* Est 1 refers to the estimated hectares where coefficients of *Field Days 1980*, *Geraldton*, *Merredin* and *Consultant 1* are set to zero.

\# Est 2 refers to the estimated hectares using coefficients set to zero as for Est 1, and using the adjusted value for the *Adviser Distance 1979* variable.

Some explanatory notes:

The actual areas planted to lupins each year were known. The time lags attributable to the absence of extension had been estimated. The estimated hectares were calculated in the following way. In Cunderdin, for example, the lag associated with Estimate 1 was 0.90 years. It was then assumed that at time 78.9, the area planted to lupins was equal to the actual area at time 78. Similarly, at time 79.9, the area planted to lupins was equal to the actual area at time 79. The estimated area at time 79 could than be calculated algebraically. Where the lag was greater than one year, such as for Greenough where the lag was 1.91 years, it was assumed that at the time 78.91. the area planted to lupins was equal to the actual area at time 77.

There were a number of complications involved with the calculations. The most serious was the effect of 1970s lupin planting areas on the early year estimates, especially where 1970s areas were substantial and time lags were large. This resulted in the unsatisfactory situation where the estimated hectares were initially more than the actual hectares. Figures for 8 shires were adjusted to overcome this problem and the discrepancies in other shires ignored (where areas involved were less than 500 hectares). In retrospect, it would probably have been wiser to have used a smoothed data curve for lupin areas - this was not done, but the overall effects are hypothesised to be minimal, and if anything, to underestimate the benefits associated with earlier start times of the diffusion process.

APPENDIX 3

Table 8

TOTAL SPENDING BY AGRICULTUREWA (actual dollars)

Year	Total $*	R & D $	R & D %	Extension $	Ext %
1978	29128252	19000198	65.2	5825650	20.0
1979	33993976	13791233	40.6	7301646	21.5
1980	39210342	16416985	41.9	5612114	14.3
1981	46577232	22397648	48.1	6009867	12.9
1982	53165108	25092695	47.2	7163329	13.5
1983	60130233	35954816	59.8	13445927	22.4
1984	69310000	34037290	49.1	14026433	20.2
1985	75880000	34938090	46.0	18412286	24.3
1986	74760000	33565217	44.9	21011377	28.1
1987	82195000	40051789	48.7	21729662	26.4
1988	97793000	45137274	46.2	24522814	25.1
1989	113230000	52013810	45.9	27975051	24.7
1990	107092000	53205804	49.7	28955115	27.0
1991	110774000	57683742	52.1	29297980	26.4
1992#	104097000	52048500	50.0	31229100	30.0
1993	109555000	54777500	50.0	32866500	30.0

* Includes all State Government funds, and Commonwealth & Industry funds, but excludes funding for the Agricultural Protection Board.

\# In this year (and for subsequent years), funds were allocated to Industry & Market Development and Sustainable Agricutural Systems rather than R & D and Extension. Fifty percent of the total was used to estimate R & D expenditure, and 30 percent extension expenditure.

Source: Department of Agriculture Western Australia Annual Reports 1977/78 to 1993/94.