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POLICY OPTIONS FOR CHEMICAL-FREE AGRICULTURE: AN LP APPROACH

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1. Introduction

Although the use of synthetic fertilisers and pesticides in agriculture has increased productivity per unit of land and labour, it is increasingly recognised that this form of agriculture also has a number of drawbacks. These include net negative externalities[2], in addition to likely deterioration of private agricultural resources such as land and predators in the long run (see, for example, Department of Environment, Housing and Community Development (1978); Hodges and Arden-Clarke (1986) and Debach (1974)).

An alternative form of agriculture, in which no synthetic fertilisers and pesticides are used ('chemical-free') has been practised in Australia and overseas by some farmers. Despite the fact that this form of agriculture can be as financially rewarding as conventional agriculture[3], not many farmers practise it. Would more farmers switch to chemical-free agriculture if some of the externalities emanating from conventional agriculture were internalised? How would government policies aimed at correcting the externality problem affect the profitability of the different farming systems? These questions are addressed in this paper.

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[1] The authors thank Geoff Edwards and David Vanzetti for useful comments on earlier drafts of this paper.

[2] For a summary of the issues see Wynen and Edwards (1988).

[3] For an overview of some surveys on overseas chemical-free farming see Lampkin (1984) and Wynen and Fritz (1987), and for chemical-free farming under Australian conditions see Wynen (1988).

2. Objectives

The following agricultural policies are to be examined:

- subsidies or taxes on fertilisers and pesticides
- marketing costs of wheat

The management techniques used in conventional agriculture (which include the use f synthetic fertiliser and pesticides) can create a number of negative externalities such as damage to human health and environmental pollution. Wynen and Edwards (1987) argued that the most appropriate way of internalising these externalities is to tax fertilisers and pesticides. In this paper an attempt is made to quantify the effect of subsidies and taxes on the use of these inputs.

The other issue to be discussed is the effect of marketing costs on the relative profitability of the two farming systems. There is reason to believe that the wheat marketing system in Australia leads to marketing costs for chemical-free farmers which are higher than those for conventional farmers. These costs appear to be distortionary and influence the profitability of different enterprises, with consequences for the choice of rotation system, fertiliser rate, or farming system adopted by the farmer. However, the costs are often concealed by premiums for organic produce. In the absence of the extra costs, returns to chemical-free farmers would have been higher. What does this imply for the choice of rotation, and therefore for the use of inputs and for the return from farming?

3. Method

Linear programming is suitable for an analysis where knowledge of the impact of policies on activities is desired. This impact can occur at the farm and at the industry level. However, to predict the effects on an industry, an aggregative model is needed. In this paper a prototype model, or case study, is developed to predict the impact at the farm level. No account is taken of a downward sloping demand for agricultural output in estimating the effect of increased supply on output prices and farm revenue. The solution indicates what action individual farmers are likely to take with the implementation of policies regarding fertiliser, pesticide and output prices.

4. Data

A model was constructed for a representative wheat/livestock farm in the Eastern Riverina region. There are two versions of the model. In the first, conventional farming practices are followed. The basic data for the conventional farm are taken from Reilly and Gorlyn (undated). A second version relates to chemical-free farming. Data for this farm differ from the conventional farm according to the results of a comparative survey of chemical-free and conventional farms (Wynen 1988). This survey was conducted amongst wheat/livestock farms in south-eastern Australia for the cropping year 1985-86. The main feature of the survey is that, on average, the chemical-free farmers were as commercially viable as their conventional farmer neighbours. Although wheat yields were similar, costs (especially of fertilisers, pesticides and depreciation) were considerably lower on chemical-free farms. When imputing data for the chemical-free farm in the model it is assumed that relative input use between the two farming systems remained similar between the survey period and 1987 (for which Reilly's and Godyn's figures are valid).

5. Formulation of problem

The linear programming formulation is fairly standard. The variable maximised is gross margin (total revenue minus variable costs). Risk is not included, nor are intertemporal considerations, such as investment or discounting. While this is not a dynamic model, time is included implicitly by specifying entire rotations in the model (see, for example, Dent, Harrison and Woodford (1986)). They are included to reflect management requirements concerning issues such as a farmer's objectives, soil fertility considerations and pest problems (including insects, weeds, and diseases). Of course, these rotations apply to each paddock, with the stage in the rotation varying from paddock to paddock. Hence, inputs are used and outputs accrue over the whole of the rotation period, but are included here as the total of that period divided by the number of years in the rotation, that is, on a yearly basis. This is shown in Table 3. The objective function represents the gross margin, and is maximised subject to the constraints listed below.

a. Land:

The land resource consists of two components: quantity and quality.

Total area operated consists of arable and non-arable land. The figures used in this model are as follows:

- total area operated: 1000 ha
- arable area: 700 ha
- non-arable area: 300 ha

For this analysis it is assumed that soil quality is the same for both farms. One of the criteria for the selection of the conventional farms in the survey by Wynen (1988) was similarity in soil type to that on the chemical-free farms. However, a factor which influences the quality of the soil is the farm management system. With the change in management system a change in soil quality is likely. Of the 26 farmers interviewed by Wynen (1988), none thought that the quality of the soil on chemical-free farms was worse than on the conventional farms, while 4 conventional and 3 chemical-free farmers thought that buyers would be willing to pay more for the land due to improved soil quality. No physical data were collected on this variable. However, the difference, if present, is assumed to be expressed in output per unit of input.

b. Fertiliser:

For the cropped area five levels of nutrients are included in the model. On the non-cropped arable area fertilisers are only used in the two rotations with an emphasis on stocking (rotations 2 and 4; see below).

The type of nutrients used are rock phosphate (15.5 per cent P) and Starter 12 (11.7 per cent N, 22.7 per cent P, and 2.3 per cent S) for the chemical-free and conventional farmer, respectively. The difference between the two types of fertiliser, apart from the difference in nutrient levels, is that the phosphorus in rock phosphate is not water-soluable, while that in Starter 12 is. This means that Starter 12 causes more off-farm pollution, for example in water ways. Details of the levels of nutrients and their effect on wheat yields are shown in Appendix 1.

The chemical-free farm also applies lime 18 months before planting of the first crop in the rotation. This is used partly to combat certain weeds.

c. Pesticides:

Pesticides in the cropping phase are used only on the conventional farm. It is assumed that a decreased rate would mean rapidly decreasing returns per unit of input, and that therefore the recommended rates are applied.

For the first crop one herbicide application in the spring is applied to prevent weeds from seeding. Other herbicide and insecticide applications are as in Reilly and Godyn (undated).

d. Livestock:

Most of the livestock figures are taken from Reilly and Godyn (undated) for a medium wool self replacing merino flock. As no differences were indicated between livestock numbers per hectare or wool yield per sheep in the comparison between chemical-free and conventional farms (Wynen 1988), the same figures for these variables are used for the two farming systems in this model. The exception is the cost for veterinary chemicals, which is calculated for the chemical-free farmer as 26 per cent of that for the conventional farm. This figure is based on the averages used by chemical-free and conventional farmers in Wynen (1988, p.18). Results from the survey are also used in the decision to cut the stocking rate suggested in Reilly and Godyn (undated) by almost 40 per cent (from 8 to 5 dry sheep equivalent). This appeared to be a more appropriate figure both in terms of stocking rate and of income per hectare stocked. Stocking rates in the different rotations are adjusted for area in oats where oats is grown for dual purpose (grain and grazing).

e. Labour:

Labour is not constrained. It is assumed that the owner/operator would supply the labour or that the labour was hired. The rate is set at $10 per hour, and is calculated totally as a variable cost.

f. Machinery and equipment:

Reilly and Godyn (undated) calculated the variable and fixed costs of packages of machinery, which included a tractor, disc plough, scarifier, wideline cultivator, combine, spray unit and a harvester. Two different packages are used for the two farms. For the chemical-free farm a package totalling $196,618 is used, while the conventional farm is attributed machinery to a value of $317,910 (recommended price less 12.5 per cent for the tractor and 20 per cent for implements). The reason for the different treatments of the two farms in the model is the considerable difference in depreciation of machinery and equipment per hectare operated in the survey of chemical-free and conventional farmers (Wynen 1988, p.24). This was at least partly due to a difference in size of the biggest tractor. The packages of machinery used for the chemical-free and the conventional farm in the model included a tractor which was 17.3 and 17.7 per cent larger than the averages in the survey for chemical-free and conventional farms, respectively. Thus, although figures for exactly similar machinery and equipment was not available, relative values were maintained.

Variable costs for planting are included as in Reilly and Godyn (undated), irrespective of yields. However, harvesting costs are dependent on yield.

g. Yield:

Yield figures for the different crops for a particular fertiliser rate are taken from Reilly and Godyn (undated) for the conventional farmer. Also two higher and two lower levels than this basic level of fertiliser are imputed in the model. Yields for those levels are based on a quadratic fertiliser response function, as shown in Table 1.

Table 1: Fertiliser response functions

Crop	Chemical-free	Conventional
Wheat	$0.7 + 10.75x - 18.75x^2$	$0.7 + 43x - 300x^2$
Oats	$0.8 + 6.25x - 11.25x^2$	$0.8 + 25x - 180x^2$
Peas		$0.7 + 8x - 19.2x^2$

x = fertiliser levels (t/ha)

Yields at the basic level of nutrient application for the chemical-free farmer are based on relative figures in the survey by Wynen (1988). For the other levels , similar response functions as those employed for the conventional farmer are used. Yields calculated in that way for the model are shown in Appendix 1, Tables A.1.1 to A.1.4.

h. Rotation requirements:

There are four different rotations, the details of which are shown in Tables 2 and 3. The basic rotation (rotation 1) is similar to the actual rotation on a chemical-free farm and a conventional neighbour farm in the Eastern Riverina area in 1985-86 (Wynen 1988). The chemical-free farmer included some rye in his rotation. However, since the inputs used and returns from this crop were similar to those of a second wheat crop, it has been included as wheat for simplicity. The remaining rotations are adaptations according to what the farmers said they might do if input and/or output prices changed.

Table 2: Rotations under chemical-free and conventional farm management

Year	Chemical-free				Conventional			
	1	2	3	4	1	2	3	4
1	w	w	w	w	w	w	w	w
2	w	o	w	w	o	o	e	e
3	p	p	o	o	p	p	w	w
4	p	p	p	p	p	p	o	o
5	p	p	p	p	p	p	p	p
6	p	p	p	p	w		p	p
7	p	p	p	p	p			w
8	p	p	p	p	p			o
9	w	w		w	w			o
10	o	o		o	p			p
11	p	o		o	p			p
12	p	p		p				
13	p	p		p				
14	p	p		p				
15	p	p		p				
16	p	p		p				
17		p						

w = wheat o = oats e = peas p = pasture

Rotations 1 and 2 are similar in cropping, with an emphasis on livestock in rotation 2. This includes increased area in oats, and fertiliser application on arable non-cropped area. In rotations 3 and 4 the cropping rate is increased as compared to rotations 1 and 2, with an emphasis on stock in rotation 4.

The number of rotations included is based on the need for keeping the computations within manageable proportions for the purpose of this paper. They are considered sufficiently diverse to enable the assessment of likely responses to policy changes.

Table 3: Percentage of arable area in crop and under pasture with different rotation systems.

	Rotation							
	1		2		3		4	
	C-F	C	C-F	C	C-F	C	C-F	C
Wheat (year 1)	13	27	12	20	13	17	13	18
Wheat (year 2)	6	0	0	0	12	17	6	9
Oats	6	9	18	20	12	17	19	27
Peas	0	0	0	0	0	17	0	9
Pasture	75	64	71	60	63	33	62	37

C-F = Chemical-free C = Conventional

6. Results

The effects of changes in fertiliser prices on fertiliser use (both through changes in rotation and in fertiliser rates) are shown in Table 4. Entries under 'fertiliser prices' are those prices at which a switch in rotation or in fertiliser level within a rotation occurs. The values were obtained by parameterising fertiliser prices in the LP run. This means that the model determines the price of fertiliser at which a change in rotation system or fertiliser rate occurs.

For the chemical-free farmer a subsidy of over 33 per cent, decreasing the price to under $60 per tonne, would induce the farmer to increase the amount of fertiliser used per hectare by 17 per cent. This increases the total amount of rock phosphate used from 42.0 to 49.0 tonnes on that farm. If the fertiliser price was reduced to over 54 per cent of the actual price, the optimum strategy for the farmer would be to change to a short rotation with the emphasis on livestock (rotation 4). This would cause an increase in the use of rock phosphate to 73.5 tonnes, almost double that used in reality. A reduction in rock phosphate used would be brought about by a tax of 69 per cent or $62 per tonne, with a resulting drop to 35.0 tonnes used in total.

A smaller relative reduction in fertiliser price (29 per cent) is needed for the conventional farmer to increase the fertiliser rate by 17 percent, and total fertiliser used by 2 tonnes to [illegible]7.5 tonnes, although the absolute amount is larger ($117 per tonne). When the fertiliser price is dropped by over 33 per cent ($131 per tonne), the farmer would switch to the cropping-intensive rotation 3. This would, in addition to considerably increasing the total use of fertiliser, also increase the use of pesticides by 19 per cent. A decrease in fertiliser use per hectare in the rotation is brought about by a price increase of 36 per cent or $142 per tonne, causing the total fertiliser use to drop to 12.6 tonnes.

Table 4: Fertiliser price, fertiliser and pesticide use and gross margins

Fertiliser Price		Rotation	Fertiliser Use			Pest. Use**	Gross Margin
($/t)	(%)*		(kgs/ha)	(%)#	(tonnes)	($)	($'000)
Chemical-free:							
0	-100	4	280	+17	73.5	687	43.1
41	-54	1	280	+17	49.0	799	40.1
60	-33	1	240	0	42.0	799	39.2
90	**0**	**1**	**240**	**0**	**42.0**	**799**	**37.9**
152	+69	1	200	-17	35.0	799	35.3
246	+173	1	160	-33	28.0	799	32.1
341	+279	1	120	-50	21.0	799	29.4
Conventional:							
0	-100	3	70	+17	44.8	7764	44.8
226	-44	3	60	0	38.5	7764	34.7
269	-33	1	70	+17	17.5	6524	33.0
283	-29	1	60	0	15.4	6524	33.8
400	**0**	**1**	**60**	**0**	**15.4**	**6524**	**31.0**
542	+36	1	50	-17	12.6	6524	28.8

* Difference between fertiliser price and actual fertiliser price: Rock phosphate = $90 / ha Starter 12 = $400 / ha

\# Difference in fertiliser used per hectare between present and actual price.

** Pesticides include all biocides used in the production process, such as weedicides, insecticides, fungicides, and veterinary chemicals.

Recent fertiliser bounties, terminated in July 1988, were allocated according to the available (that is, water soluable) phosphate content of the fertilisers. This means that those chemical-free farmers who applied rock phosphate did not qualify for any subsidies. Conventional farmers who used synthetic fertilisers with the highest available phosphates, and therefore with the highest potential damage to the environment, received the highest subsidies. This amounted to $188 per tonne of phosphates for those fertilisers with a higher than 15 per cent available phosphate rate. This would have amounted to $41 per tonne for Starter 12. The results in this analysis suggest that the removal of the subsidy would have had no effect on fertiliser use. However, this conclusion reflects the linearities in this model. At other levels of use, a price change may have made a difference to the rate of application.

Taxes on pesticides (not shown in the tables) do not change the desirability of particular rotations. They merely decrease the farm revenue by the amount of the tax.

In Tables 5 and 6 the same variables as in Table 4 are shown for changes in output prices. Table 5 refers to the chemical-free farmer and Table 6 to the conventional farmer.

The price of wheat quoted in Reilly and Godyn (undated) for 1987 was $75. Prices were varied $10 and $20 higher and lower than this basis. The effects on the rotation, fertiliser rate, total fertiliser and pesticides used, and the gross margin were assessed.

For both the chemical-free and the conventional farmer the main effect of changes in wheat prices is a change in gross margin. The exception is where wheat prices are at the lowest ($55 per tonne). At this price the chemical-free farmer would include more oats in the rotation (rotation 2) to keep more livestock. Consequently, the total amount of fertiliser used is increased at that level.

With variations in wheat prices the gross margin on the chemical-free farm varies between $31.8 and $44.1, which is a variation of 16 per cent on either side of the base price. On the conventional farm comparable figures are $21.8 and $40.2, a variation of 30 per cent on either side of gross margin obtainable with normal wheat prices. This indicates that variations in wheat prices might have a more destabilising effect on conventional farms than on chemical-free farms. This is because conventional farmers are cropping more intensively than chemical-free farmers.

Chemical-free farmers who sell wheat in the organic market might incur increased wheat marketing costs. These farmers would only enter that market if the premiums are higher than those extra marketing costs. This means that those farmers sell the wheat for $75 per tonne or higher. No changes in rotation and fertiliser rate are likely within the range examined in this paper (up til $95 per tonne). This indicates that the increased marketing costs only mean a transfer of income away from chemical-free farmers.

Table 5: Effect of changes in output prices on fertiliser and pesticide use and on gross margin on a chemical-free farm

Output Price	Rotation	Fertiliser Use		Pesticide Use**	Gross Margin
($/t)		(kgs/ha)	(tonnes)	($)	($'000)
Wheat:					
55	2	240	49.7	760	31.8
65	1	240	42.0	799	34.9
75	**1**	**240**	**42.0**	**799**	**37.9**
85	1	240	42.0	799	41.0
95	1	240	42.0	799	44.1
Livestock:					
20 % decrease:	4	240	63.0	687	24.6
20 % increase:	1	240	42.0	799	51.7
Wheat and livestock					
Wheat: $55					
Livestock:					
20 % decr.:	2	240	49.7	760	19.3
20 % incr.:	2	240	49.7	760	46.2
Wheat: $95					
Livestock:					
20% decr.:	1	240	42.0	799	30.4
20% incr.:	1	240	42.0	799	57.7

** Pesticides include all biocides used in the production process, such as weedicides, insecticides, fungicides, and veterinary chemicals.

The effects of changes in prices for livestock products (wool and meat) were also explored. Prices were increased or decreased by 20 per cent. The decrease in livestock prices caused both farmers to change towards more intensive cropping (rotations 3 or 4). In the case of the chemical-free farmer the optimal rotation was that with an emphasis on stocking within a shorter rotation (rotation 4). This might have been the case because costs of rotation 3 outweigh the benefits from rotation 4. The optimal rotation for the conventional farmer is the one with the emphasis on cropping (rotation 3). This results in a considerable increase in fertiliser and pesticide use (an increase of 150 and 19 per cent, respectively). The gross margins on both farms are more than halved.

Table 6: Effect of changes in output prices on fertiliser and pesticide use and on gross margin on a conventional farm

Output Price	Rotation	Fertiliser Use		Pesticide Use**	Gross Margin
($/t)		(kgs/ha)	(tonnes)	($)	($'000)
<u>Wheat:</u>					
55	1	60	15.4	6524	21.8
65	1	60	15.4	6524	26.4
75	**1**	**60**	**15.4**	**6524**	**31.0**
85	1	60	15.4	6524	35.6
95	1	60	15.4	6524	40.2
<u>Livestock:</u>					
20 % decrease:	3	60	38.5	7764	20.2
20 % increase:	1	60	15.4	6524	43.3
<u>Wheat and livestock</u>					
Wheat: $55					
Livestock:					
20 % decr.:	3	60	38.5	7764	11.6
20 % incr.:	1	60	15.4	6524	34.0
Wheat: $95					
Livestock:					
20% decr.:	3	60	38.5	7764	28.9
20% incr.:	1	60	15.4	6524	52.4

** Pesticides include all biocides used in the production process, such as weedicides, insecticides, fungicides, and veterinary chemicals.

When these two factors are combined (changes in wheat and livestock prices), changes in rotation seem to depend on wheat prices for the chemical-free farmer, and on livestock prices for the conventional farmer. The chemical-free farmer moves towards more stock with low wheat prices, and the conventional farmer towards more crop with low livestock prices.

7. Implications and Conclusions

With present policies, the most profitable management strategies for both farmers are to adopt the rotation with a relatively low cropping intensity (rotation 1), and a relatively high rate of nutrient application.

Negative externalities from the use of synthetic fertilisers can be decreased by encouraging conventional farmers to use less fertilisers or to convert to chemical-free farming. This can be achieved by taxing fertilisers used on conventional farms. However, these taxes need to be considerable. An increase of 36 per cent (or $142 per hectare) causes a decrease of fertiliser use by 18 per cent and gross margin by 7 per cent ($2,200). Reasons for not converting from conventional to chemical-free farming are unlikely to be purely financial (Wynen 1988). A decrease in the gross margin of only $2,200 is unlikely to persuade farmers to switch to chemical-free farming. However, a policy of taxing production techniques which create negative externalities is a welfare-improving measure as the tax received can be used to clean up the environment.

Discouragement of the use of pesticides is not likely to be achieved by taxing pesticides, at least not in this industry, as taxes on pesticides do not lead to a change in optimal rotation. However, the same argument as for fertilisers regarding taxes to correct the negative externalities caused by the input, is valid here.

Negative externalities from conventional farming increase with decreasing stock prices, as conventional farmers move towards a higher cropping intensity rotation, using more fertilisers and pesticides.

Increased marketing prices for organic wheat affect the revenue of organic farmers, but not the rotation or fertiliser rate.

The results obtained here appear to be quite robust. However, there are a number of refinements that could be made to the model. First, the model is essentially static, with the dynamics being limited to the various agronomic effects that are captured in the specifications of the rotations. A multiperiod model would allow a more accurate specification of some of the activities which take place on a farm, such as investments.

The rotations specified here are determined exogeneously. In some ways it would be more satisfying if they could be determined within the model (the solutions greatly depend upon the available rotations). Endogenising the sequence of activities over time would involve, however, a considerable increase in complexity.

The model results are likely to be sensitive to the fertiliser response function. Alternative functional forms may also generate different results. Unfortunately, empirical data relating to response functions are of little assistance, as great variations have been observed from region to region, and even from farm to farm.

REFERENCES

Debach, P. (1974), Biological Control by natural enemies, Cambridge University Press.

Dent, J., Harrison, S. and Woodford, K. (1986), Farm Planning with Linear Programming: Concept and Practice, Butterworths, Sydney.

Department of Environment, Housing and Community Development (1978), A Basis for Soil Conservation Policy in Australia, Commonwealth and State Government Collaborative Soil Conservation Study 1975-77, Australian Government Publishing Service, Canberra.

Hodges, R.D., and Arden-Clarke, C. (1986), Soil Erosion in Britain, The Soil Association Ltd., Bristol, United Kingdom.

Lampkin, N. (1984), 'Studies of biological farming systems in Western Europe and North America - a literature review'. Paper presented at the 5th Conference of the International Federation for Organic Agriculture Movements.

Reilly, T. and Godyn, D. (undated), Farm Budget Handbook 1987, New South Wales Department of Agriculture.

Wynen, E. (1988), Sustainable and Conventional Farming in South-Eastern Australia: A Comparison. Discussion Paper No. 22/88, School of Economics, La Trobe University, Bundoora.

Wynen, E. and Edwards, G. (1988), 'Towards a comparison of conventional and chemical-free farming in Australia'. Unpublished paper, La Trobe University.

Wynen, E. and Fritz, S. (1987), Sustainable Agriculture: a Viable Alternative, National Association for Sustainable Agriculture, Australia, Sydney.

APPENDIX I

Table A.1.1: Estimated crop yields under rotation 1 as a function of level of fertiliser (tonne per hectare)

Item	Level of application				
	1	2	3	4	5
<u>Chemical-free farmer</u>					
Rock phosphate (t/ha):	0.12	0.16	0.20	0.24	0.28
Yield					
Wheat (year 1)	1.92	2.14	2.30	2.40	2.44
Wheat (year 2)	1.72	1.94	2.10	2.20	2.24
Oats	1.39	1.51	1.60	1.65	1.67
<u>Conventional farmer</u>					
Starter 12 (t/ha):	0.03	0.04	0.05	0.06	0.07
Yield					
Wheat (year 1)	1.92	2.14	2.30	2.40	2.44
Oats	1.39	1.51	1.60	1.65	1.67

Table A.1.2: Estimated crop yields under rotation 2 as a function of level of fertiliser (tonne per hectare)

Item	Level of application				
	1	2	3	4	5
<u>Chemical-free farmer</u>					
Rock phosphate (t/ha):	0.12	0.16	0.20	0.24	0.28
Yield					
Wheat (year 1)	1.87	2.09	2.25	2.35	2.39
Oats	1.29	1.41	1.50	1.55	1.57
<u>Conventional farmer</u>					
Starter 12 (t/ha):	0.03	0.04	0.05	0.06	0.07
Yield					
Wheat (year 1)	1.82	2.04	2.20	2.30	2.34
Oats	1.29	1.41	1.50	1.55	1.57

Table A.1.3: Estimated crop yields under rotation 3 as a function of level of fertiliser (tonne per hectare)

Item	Level of application				
	1	2	3	4	5
Chemical-free farmer					
Rock phosphate (t/ha):	0.12	0.16	0.20	0.24	0.28
Yield					
Wheat (year 1)	1.62	1.84	2.00	2.10	2.14
Wheat (year 2)	1.42	1.64	1.80	1.90	1.94
Oats	1.01	1.21	1.30	1.35	1.37
Conventional farmer					
Starter 12 (t/ha):	0.03	0.04	0.05	0.06	0.07
Yield					
Wheat (year 1)	1.47	1.69	1.85	1.95	1.99
Wheat (year 2)	1.27	1.49	1.65	1.75	1.79
Peas	0.89	1.01	1.10	1.17	1.21
Oats	0.99	1.11	1.20	1.25	1.27

Table A.1.4: Estimated crop yields under rotation 4 as a function of level of fertiliser (tonne per hectare)

Item	Level of application				
	1	2	3	4	5
Chemical-free farmer					
Rock phosphate (t/ha):	0.12	0.16	0.20	0.24	0.28
Yield					
Wheat (year 1)	1.62	1.84	2.00	2.10	2.14
Wheat (year 2)	1.42	1.64	1.80	1.90	1.94
Oats	1.01	1.21	1.30	1.35	1.37
Conventional farmer					
Starter 12 (t/ha):	0.03	0.04	0.05	0.06	0.07
Yield					
Wheat (year 1)	1.47	1.69	1.85	1.95	1.99
Wheat (year 2)	1.27	1.49	1.65	1.75	1.79
Peas	0.89	1.01	1.10	1.17	1.21
Oats	0.99	1.11	1.20	1.25	1.27