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Investigating the long-term impact of stockless organic conversion strategies

by

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ABSTRACT

Short-term leguminous green manures have traditionally been used to accumulate nitrogen during the organic conversion period. In a stocked system the in-conversion land may be used for grazing. However, in a stockless system land is effectively removed from production and substantial financial penalties may be incurred. Both the short and long-term effects of organic conversion are important. The legacy of the conversion strategies, i.e. the effects on the second (winter beans) and third (winter oats) organic crops were investigated on two soil textures. The strategies were:

1. two-years' red clover-ryegrass green manure
2. two-years' hairy vetch green manure
3. red clover for seed production, then a red clover-ryegrass green manure
4. spring wheat under-sown with red clover, then a red clover green manure
5. spring oats, then winter beans
6. spring wheat, then winter beans
7. spring wheat under-sown with red clover, then a barley-pea intercrop

Post conversion the first organic crop was winter wheat.

Conversion strategy had a significant impact on organic bean yield, which ranged from 2.8 to 3.6 t ha^{-1} and organic oat yield, which ranged from 3.2 to 4.2 t ha^{-1}. In the organic bean crop, weed abundance prior to harvest, along with soil texture, accounted for 70% of yield variation. For the oats, soil mineral nitrogen in November together with weed abundance in April, accounted for 72% of the variation in yield. The impact of conversion strategies on soil mineral nitrogen levels were still detectable three years post conversion (after the winter oat harvest in 2004).

A land quality index (LQI) was developed which linked crop yield, through regression analysis, with crop price. Calculations of the LQI for the two organic crops showed that the spring wheat under-sown with red clover had the highest index value, but when the gross margins for the entire rotation were calculated, the red clover for seed production was ranked as the top strategy. However, this strategy relies on securing specialist markets and is unlikely to be appropriate for all growers.

Overall, the two years' red clover strategy would suit the risk-averse grower due to the high levels of soil mineral nitrogen and good weed control this strategy affords and the overall gross margin derived over the five year period from conversion to the end of the first three organic crops. These results highlight the importance of the fertility-building conversion period in terms of its effect on soil nutrient levels, weed abundance and economic viability.

SUMMARY

Introduction

Since March 2003, there has been an increase in the total area of organic and in-conversion land in England from approximately 251,800 ha to 259,372 ha in January 2005. This is a much slower expansion than that noted in previous years and reflects uncertainties concerning the organic market and the implementation of the Common Agricultural Policy (CAP) reform. Of the 2004 figure, 28,995 ha (11%) was in-conversion and 230,377 ha (89%) was fully organic. Whilst the fully organic area increased by 4% from January 2004, the area of land in-conversion fell by 21% indicating a decline in the land area entering organic production. Despite the increase in fully organic land it still only accounts for approximately 3% of all English farmland.

To qualify for an organic premium, UK land must first undergo a conversion period, typically of two years. From the start of that period all applications of prohibited substances (e.g. pesticides and chemical fertilisers) must cease. The main objective of the conversion period is to increase soil fertility, usually through nitrogen (N) fixed from grass clover leys. Traditionally, short-term leguminous green manures have been used to accumulate nitrogen during the organic conversion period and in a stocked system the in-conversion land may be used for grazing. However, in a stockless system land is effectively removed from production and substantial financial penalties may be incurred. Moreover, the introduction of a livestock enterprise can be a severe financial deterrent to conversion as a result of the capital investment required. This has acted as an incentive for the development of financially viable stockless organic systems. These systems may offset the cost of organic conversion in two ways, a) by maximising the yield of the first organic crop or b) by using commercial cropping during the conversion period to generate income.

In a stockless system the usual conversion strategy is a red clover (*Trifolium pratense*)-ryegrass (*Lolium* spp.) green manure. However, the choice of conversion cropping strategy can have important effects and both the short and longer-term legacy of the conversion period are important. For example, conversion strategies that include cash cropping may give a better return in the short-term than the traditional red clover green manure strategy. However, the longer-term effects of cash cropping during the conversion period are also important. In particular, the effects on the following organic crop yields, and as a result organic gross margins (output less variable costs), are of crucial importance to those considering organic conversion.

A previous HGCA-funded project (no. 2313 – Project Report 307 – Organic conversion strategies for stockless farming) investigated the effects of seven conversion strategies on a subsequent organic winter wheat crop at Bunny, Nottinghamshire. The design of this experiment allowed a comparison between the traditional red clover green manure strategy and a wide range of other strategies. Several strategies were included that would not have qualified as legitimate conversion strategies at the start of the conversion period (1999) due to their lack of fertility building. These strategies included commercial cropping to generate income during conversion and as a result reduce the financial pressure associated with this period. However, these strategies could result in reduced soil fertility, poorer yields and longer-term financial losses. Project Report 307 looked at the shorter-term effects of using conversion strategies other than the typical red clover green manure strategy (up to the end of the first organic crop). To fully endorse any of the strategies recommended, longer-term experiments were needed so that the effect on subsequent organic crops could be determined.

Aims and objectives

This research aimed to determine the long-term impacts of organic conversion strategies for stockless farming systems. Building on the work of Project Report 307 it aimed to identify the effect of seven different conversion strategies on both the agronomic and economic performance of the second and third organic crops. The objectives of this study are listed below:

- To identify the effects of the seven conversion strategies on the second and third organic crops.
- To investigate any differences in the weed population and community as a result of the seven conversion strategies and to clarify the effects on crop performance.
- To identify changes in soil porosity and soil mineral nitrogen in the second and third post-conversion crops.
- To determine the economic performance of the second and third organic crops based on experimental yields.
- To use the data from the field experiment in conjunction with the data on economic performance to develop a ‘land quality index’.
- To review the conversion strategies suggested in Project Report 307 and if necessary revise those recommendations taking longer-term factors into consideration.

Materials and Methods

Field experiment

A field experiment was established in 1999 at Bunny Park Farm, University of Nottingham when 20 hectares were entered into organic conversion. Within that site 28 plots were established (each 12.5 x 30m) which were sown with a red clover-ryegrass green manure on 5 September 1999. Seven conversion strategies were implemented and these were replicated four times in a randomised block design. Two of the conversion strategies were based on the previously sown red clover-ryegrass green manure (RCRC and CSRC, see Table 1), and five other strategies were implemented in March 2000 (Table 1). The abbreviations listed in Table 1 will be used from this point forward to denote each conversion strategy. Soil texture on the site ranged from sandy loam to sandy clay at a depth of 0-30 cm. To account for this variation, blocking was used (blocks 1 and 2, sandy loam and blocks 3 and 4, sandy clay). However, for simplicity, soil in blocks 1 and 2 will be referred to as sand, and in blocks 3 and 4, clay throughout this report. Conversion was completed in 2001 and a crop of organic wheat was planted over the entire experimental area. This was followed by the second (winter beans) and third (winter oats) organic crops which were the subject of the current experiment.

During the current study soil nutrients were measured on a regular basis from the top 90 cm of the soil. Weed burden and weed species were also monitored throughout the growing season in both winter beans and winter oats. In addition, crop development, growth and yield were assessed.

Table 1. Organic conversion strategies with subsequent organic cropping, Bunny Park.

u/s indicates under-sown with red clover.

	HGCA 2313			Current Study	
Strategy	**Conversion Year 1**	**Conversion Year 2**	**Organic crop Year 3**	**Organic crop Year 4**	**Organic crop Year 5**
RCRC	red clover ryegrass	red clover ryegrass	winter wheat	winter beans	winter oats
VEVE	vetch	vetch, rye	winter wheat	winter beans	winter oats
CSRC	red clover seed ryegrass	red clover	winter wheat	winter beans	winter oats
UWRC	u/s spring wheat	red clover ryegrass	winter wheat	winter beans	winter oats
OABE	spring oats	winter beans	winter wheat	winter beans	winter oats
WHBE	spring wheat	winter beans	winter wheat	winter beans	winter oats
UWBP	u/s spring wheat	spring barley pea intercrop	winter wheat	winter beans	winter oats

Gross margin analysis

Gross margins were calculated for each conversion strategy for both winter beans and winter oats using the yield from the field experiment and crop prices published in the 2002/03 Organic Farm Management Handbook. Variable costs were also calculated using the same publication. To present a complete picture, gross margins were also calculated for the five year period as a whole – i.e. the two-year conversion and three year organic cropping period.

Land quality index

The crop yield and subsequent revenue from any area of land is the output from that land, and is directly influenced by land quality. Crop yield was used as the most objective proxy for land quality, being the most appropriate measure of productive capacity. This allowed the calculation of an objective value of land quality through the construction of a measured land quality index (LQI_m) based upon the monetary value of yield produced. In developing the LQI_m, data collected in the course of each field season was used and linked to the monetary value of the crop yield. The initial process in determining land quality was to calculate the output (yield x price per tonne, £ ha^{-1}) for the two organic crops of winter beans and winter oats. To calculate LQI_m the strategy with the highest output was identified. Dividing the output of each strategy in turn by this value and multiplying by 100 then calculated the LQI_m.

In order to explain and estimate the impact of individual properties of the land (e.g. weed burden) on its productive capacity, a regression analysis was undertaken, which also permitted a predicted land quality index (LQI_p) to be determined. This LQI_p was derived from regression analysis that sought to explain variation in output according to factors influencing land productivity. Variables selected from the field experiment were regressed in simple or multiple linear regression models taking into account soil texture as groups when appropriate. Using the results of the regression analysis a winter bean and winter oat model were determined. These models were used to predict the effect of the observed input (e.g. soil mineral nitrogen) on the yield (output) of each crop. The predicted yield was then multiplied by the price of the crop per tonne and the LQI_p was calculated as described above for the LQI_m.

Calculation of average and marginal value product

An average value product (AVP), which determines the average value of one unit of input in terms of output (£ ha^{-1}), was calculated for the predicted output. Due to the restrictive nature of this measurement (which assumes all variation in output is determined by the one input factor) a marginal value product (MVP), which calculates the monetary value (in terms of output gained or lost) of each additional unit of input, was also calculated.

Results

Combine yield

Winter bean yields from VEVE, UWRC, UWBP and CSRC were significantly higher (P=0.02) than from WHBE and RCRC (Table 2). Winter oat yield showed a clear effect of conversion strategy ranging from 3.2 t ha^{-1} to 4.2 t ha^{-1} (P=0.01, Table 2). Yields from CSRC, UWRC and RCRC were significantly larger than those from OABE. In addition, winter oat yields from CSRC and UWRC were also significantly larger than those from WHBE. There was no significant effect of soil texture on either winter bean or winter oat yield.

Table 2. The effect of conversion strategy on winter bean and winter oat combine yield

Conversion strategy	Winter bean yield (t ha^{-1}) at 14% moisture	Winter oat yield (t ha^{-1}) at 15% moisture
RCRC	2.8	3.8
VEVE	3.6	3.6
CSRC	3.4	4.2
UWRC	3.6	4.2
OABE	3.1	3.2
WHBE	2.8	3.3
UWBP	3.5	3.5
P Value	0.02	0.01
SED (12 df)	0.240	0.238

Soil mineral nitrogen

At the start of the current experiment (September 2002) the clover-based strategies, RCRC, CSRC and UWRC, had the most soil mineral nitrogen (SMN) (P<0.01, Table 3). The highest values for SMN were recorded from the CSRC strategy in both February and November 2003 (winter beans). In February 2003 this was significantly different from that recorded in all the other conversion strategies (P<0.05). In February 2004 (winter oats) there was a trend for the more exploitative strategies, WHBE, OABE and UWBP to have lower levels of SMN (0-90 cm) although this was not significant (Table 3). However, after oats were harvested (August 2004) the CSRC, RCRC, UWRC and UWBP strategies had significantly more SMN than the OABE/WHBE strategies (P=0.011). There was no significant effect of soil texture on SMN on any of the five sampling dates.

SMN levels varied over time with the most SMN being recorded in November 2003. More SMN was recorded at the start of the current experiment than at the end. Moreover, the range of SMN values between conversion strategies was 22.6 kg N ha^{-1} in September 2002 but only 7 kg N ha^{-1} by August 2004.

Table 3. The effect of conversion strategy on soil mineral nitrogen (kg N ha^{-1}).

Conversion strategy	Sep 02	Feb 03	Nov 03	Feb 04	Aug 04
RCRC	37.7	37.0	83.4	30.6	23.2
VEVE	23.0	35.0	74.2	32.9	19.9
CSRC	33.7	53.3	91.0	38.8	23.4
UWRC	33.5	38.6	90.4	38.6	22.3
OABE	15.1	26.8	71.0	25.2	16.4
WHBE	15.2	26.3	64.8	24.3	16.9
UWBP	19.2	33.2	79.4	25.5	21.4
Mean	25.3	35.7	79.2	30.8	20.5
P Value	< 0.01	< 0.01	0.03	0.15	0.01
SED (12 df)	4.36	3.55	7.25	6.26	1.89

Weed burden and weed species

On 11 April, OABE and WHBE had significantly more weeds than either CSRC or UWRC (P=0.03). Furthermore, the number of weeds recorded from OABE and WHBE strategies was greater than in all five other strategies in May (P=0.001), July (P=0.007) and August 2003 (P=0.005). Transect data from each sampling date in 2004 also showed a significant effect of conversion strategy on weed number. On 26 April the WHBE strategy had more weeds than either the UWRC or VEVE strategies (P=0.037). Moreover, in both June and July 2004 (P<0.001) there were significantly more weeds recorded along transect lines from the WHBE/OABE strategies (>170) than any other strategy (<140).

There was a highly significant relationship (P<0.001) between weed number in August and winter bean yield (Figure 1). Linear regression with groups showed that crops with the same number of weeds produced greater yields on sandy soil than on clay soil (R^2 = 0.70). In the oat crop, SMN in November together with weed abundance in April, accounted for 72% of the variation in yield (Equation 1)

Equation 1: $Y = 4.196-0.192 \times \text{sqrt (weed no.)} + 0.01837 \times \text{SMN}$ ($P<0.001$, $R^2=0.72$)

Although the weed population on the site was fairly diverse it was dominated by a few species. Species with the largest biomass in 2003 were ivy-leaved speedwell (*Veronica hederifolia*), scentless mayweed (*Tripleurospermum inodorum*), knotgrass (*Polygonum aviculare*), creeping thistle (*Cirsium arvense*), volunteer cereals (*Triticum aestivum* and *Avena fatua*), fat hen (*Chenopodium album*) and orache (*Atriplex patula*). In 2004 the dominant species were volunteer beans (*Vicia faba*), mayweed, creeping thistle and poppy (*Papaver rhoeas*).

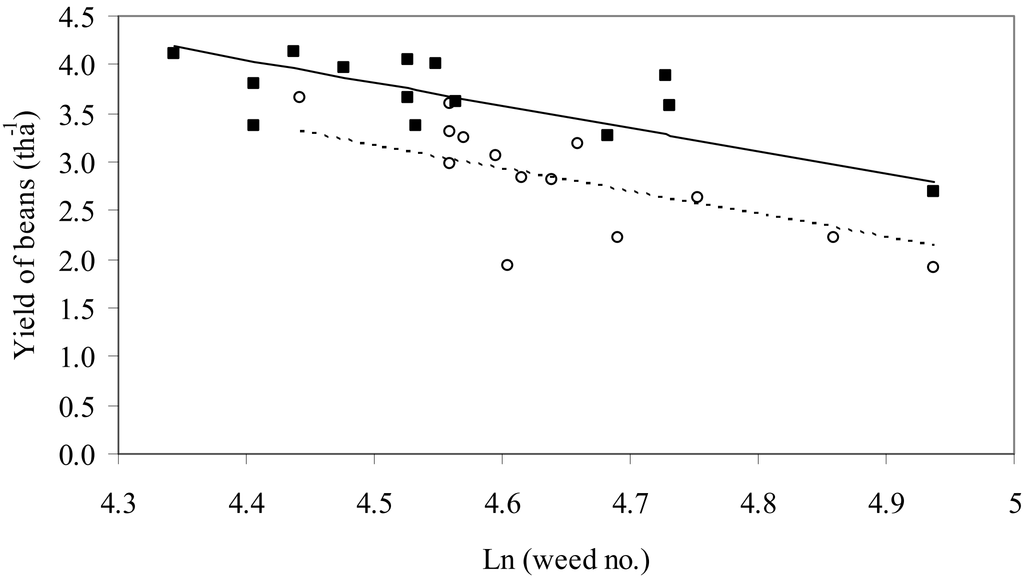

Figure 1. Linear regression of bean yield on ln (weed number) per line transect on 6 August. ■ sand y = 13.73 -2.347x ln(weed no.); ○ clay y=14.38-2.347x ln(weed no.). R^2=0.70

Gross Margins

The average gross margin for the winter bean crop was £543 ha^{-1} with a range from £448 ha^{-1} from the RCRC strategy to £616 ha^{-1} from the VEVE strategy (Table 4). In the winter oat crop the average gross margin was slightly lower at £515 ha^{-1}, ranging from £445 ha^{-1} in the OABE strategy to £592 ha^{-1} in both CSRC and UWRC strategies (Table 4). The strategies with the best gross margins over the five-year period were the three clover-based strategies of CSRC, RCRC and UWRC (Table 4). CSRC had a gross margin more than £100 higher than any other strategy, helped by the fact that it was one of only two strategies to have a positive gross margin for the conversion period. In contrast, the strategies with a more exploitative conversion period had lower annual average gross margins for the five-year period although OABE was ranked above the VEVE strategy.

Land Quality Index

The calculation of the LQI_m for the organic beans and oats showed that UWRC (100), CSRC (96.73) and VEVE (93.89) were the strategies with the highest index values (Table 5). Four of the strategies had an index value of more than 90 whilst the remaining three strategies had an index of less than 84. The regression models for the calculation of predicted yield were

$Y = a + Sg + b \ln BWt_1$ for the winter beans and $Y = a + Sg + b_1 OAv_1 + b_2 \ln OWq_1$ for the winter oats with *Y* indicating the output in t ha^{-1}of either beans or oats, *a* the intercept, *Sg* the marginal soil intercept coefficient, *b* the slope coefficient, BWt_1 weed number in the bean crop, OAv^1 soil mineral nitrogen and OWq_1 the number of weeds in the winter oat crop. Using these models to calculate yield, and subsequently LQI_p, the top three strategies were similarly UWRC (100), CSRC (98.75) and UWBP (95.57) and five strategies had an LQI_p of more than 90.

Table 4. Annual average gross margins for the current experiment (second and third organic crops) and five-year organic rotation.

	Current experiment			Conversion and organic cropping		
Conversion Strategy	Bean GM £ ha^{-1}	Oat GM £ ha^{-1}	GM, 2 organic crops £ ha^{-1}	*GM conversion period £ ha^{-1}	GM 3 organic crops £ ha^{-1}	GM Five-year rotation £ ha^{-1}
RCRC	448	528	488	-39	620	357
VEVE	616	499	558	-106	555	291
CSRC	562	592	577	199	633	459
UWRC	608	592	600	-70	633	352
OABE	512	445	479	29	497	310
WHBE	460	459	460	-15	466	274
UWBP	592	493	543	-66	505	277
Mean	543	515	529	-10	558	331

*NB. Data presented is in the absence of subsidies.

Table 5. LQI_m and LQI_p for two organic crops.

Conversion Strategy	Bean output £ ha^{-1}	Oat output £ ha^{-1}	TVP £ ha^{-1}	LQI_m	Predicted Bean output £ ha^{-1}	Predicted Oat output £ ha^{-1}	TVP £ ha^{-1}	LQI_p
RCRC	556	602	1158	83.79	652	589	1242	92.69
VEVE	724	573	1297	93.89	670	595	1264	94.39
CSRC	670	666	1336	96.73	692	631	1323	98.75
UWRC	716	666	1382	100.00	697	643	1340	100.00
OABE	619	518	1138	82.41	571	559	1131	84.41
WHBE	568	533	1102	79.71	569	524	1093	81.59
UWBP	700	567	1267	91.69	699	582	1280	95.57

AVP and MVP

For winter beans the AVP of weed number varied from £179.48 to £3.49 for sand soil and £166.52 to £2.63 for clay soil when weed input was 10 and 150 respectively. Under the same conditions the MVP for both sand and clay ranged from -£32.54 to -£3.24; indicating that the loss of value from an extra unit of weed number is lower at higher total weed abundance. As the selected winter oat model was a multiple regression involving two independent variables it was necessary to calculate both AVP and MVP twice; firstly when weed abundance was varied and SMN was held constant and secondly when SMN was varied and weed abundance was held constant. Under the first scenario the AVP had a range of £72.27 (weed input 10) to £3.48 (weed input 150) for the sand soil and £74.08 to £3.60 for the clay soil under the same weed input scenarios. In the second case the AVP ranged from £35.33 when N input was 10 to £5.41 when N input was 150 for sand soil and £36.49 to £5.49 under the same conditions in clay. The MVP was the same for all input scenarios (£3.27); indicating the value of an additional unit of N input was worth £3.27 ha^{-1}.

Discussion

Significant differences in crop yields were recorded in both the winter bean and winter oat crops. Beans were not responsive to SMN levels, i.e. bean yield did not increase in those strategies with the most SMN. However, winter oat yield was higher from those plots with a fertility building conversion period (those strategies with the most SMN) than from those with a higher proportion of cash cropping. That the differences in SMN were still apparent after the third organic crop suggested that the conversion strategies had long lasting consequences. Differences in SMN persisted into the organic rotation through variation in the mineralisation rates (as a result of differences in residue composition) of the green manure and crop residues added in the conversion period.

Conversion strategy differences in the weed population and community had an important influence on crop performance. OABE and WHBE strategies had significantly greater weed abundance than the other conversion strategies throughout both the organic bean and oat crops. The difference in weed number originated in the conversion period and was maintained throughout the rotation via changes in the weed seed bank together with the vegetative spread of weed species such as thistles. Regression analysis showed that weed abundance had an important influence on the yield of both winter beans and winter oats.

In the current experiment crop yield was used as the initial determinant of land quality as the measure of the land's productive capacity. This was linked with the monetary value of that output to obtain a land quality index. An indexing approach was chosen so that an objective, easy to understand measure of land quality could be obtained. The measured value of land quality as considered over the beans and oats crops and determined by the LQI_m was greatest in the UWRC (100), CSRC (96.73) and VEVE (93.89) strategies; land quality as measured through the LQI_p was greatest in UWRC (100), CSRC (98.75) and UWBP (95.57). Summarising the findings of the gross margin analysis, when considered over the five year period, the gross margins were greatest in the CSRC (£459 ha^{-1}), RCRC (£357 ha^{-1}) and UWRC (£352 ha^{-1}) strategies.

In agreement with HGCA 2313, the first strategy that would be recommended to a risk-averse grower would be RCRC. However, this strategy did have the lowest bean gross margin and was only ranked fifth when gross margins for just the second and third organic crops were considered. As a result, the strategy may not be suitable for those growers requiring a stable income throughout the rotation period, but weed control and SMN levels from this strategy are amongst the best of the seven strategies. Findings from the current study would also support the recommendation, to the risk-taking individual, of the CSRC strategy. The average gross margin at the end of the five-year period for CSRC was £459 ha^{-1}, over £100 ha^{-1} more than any other strategy. It also had a relatively stable income distribution throughout the five-year period as well as good soil structure, SMN levels and weed control. In contrast to the conclusions of HGCA 2313 the UWRC would not be recommended to the risk-averse grower, although it may be a suitable strategy for a risk-taking individual. The findings of the current study also do not support recommendation of the OABE strategy to a risk taking individual. This strategy had a high weed burden post conversion, low levels of SMN and was only ranked fourth in terms of annual average gross margins.

TECHNICAL REPORT

Part 1. The legacy of stockless organic conversion strategies

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ABSTRACT

The legacy of seven organic conversion strategies was investigated on two soil textures in a replicated experiment. The impacts on the first organic crop (winter wheat) have been previously reported (Huxham *et al*. 2005). This paper focuses on the impact of the conversion strategies on the second (winter beans) and third (winter oats) organic crops. The strategies were: 1. two-years' red clover-ryegrass green manure, 2. two-years' hairy vetch green manure, 3. red clover for seed production then a red clover-ryegrass green manure, 4. spring wheat under-sown with red clover, then a red clover green manure, 5. spring oats, then winter beans, 6. spring wheat, then winter beans, 7. spring wheat under-sown with red clover, then a barley-pea intercrop.

Conversion strategy had a significant impact on organic bean yield, which ranged from 2.8 to 3.6 t ha^{-1} and organic oat yield, which ranged from 3.2 to 4.2 t ha^{-1}. In the organic bean crop, weed abundance prior to harvest, along with soil texture, accounted for 70% of yield variation. For the oats, soil mineral nitrogen in November together with weed abundance in April, accounted for 72% of the variation in yield. The impact of conversion strategies on soil mineral nitrogen levels were still detectable three years post conversion (after the winter oat harvest in 2004).

The results from this study indicate that the choice of conversion crop has important longer-term implications. More exploitative conversion strategies, i.e. those with a higher proportion of cash cropping, had an increased weed burden and decreased levels of soil mineral nitrogen, leading to reduced yields of beans and oats, two and three years post conversion.

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INTRODUCTION

The choice of crop rotation is fundamental to the success of organic systems. In particular, the ratio of fertility building to fertility exploiting cropping phases has a major influence on crop yield (Younie, Watson and Squire, 1996). During the conversion from conventional to organic farming the objective is to increase soil fertility, usually through nitrogen (N) fixed from grass clover leys. In a stocked system ley management is often through grazing and harvesting for hay and silage whereas in a stockless system legumes are often cut and left as a mulch. The aim is to build up sufficient N in the system during the conversion period to support the subsequent rotation. Hence, the choice of conversion cropping during this period can have important long-term effects.

The ideal conversion crop will provide sufficient nitrogen (and other nutrients) for the following organic crops; facilitate improvements to soil structure and soil fertility; have good competitive ability against weeds; and provide a good economic return. However, both the short and longer-term legacy of the conversion period is important. For example, conversion strategies that include cash cropping may give a better return in the short-term than the traditional red clover green manure strategy. However, the longer-term effects of cash cropping during the conversion period are also important. In particular, the effects on the following organic crop yields, and as a result organic gross margins (output less variable costs), are of crucial importance to those considering organic conversion. To date, research examining the longer-term viability of systems has focused upon rotations with a red clover green manure conversion strategy (Bulson, *et al.*, 1996; Cormack, 1999; Stopes *et al* 1996; Welsh, Philipps and Cormack, 2002). As a result, there is a need for robust, replicated studies of the longer-term impacts of alternative conversion strategies on subsequent organic crops.

Building upon the work of Huxham (2003) the current study looks at the legacy of seven conversion strategies in terms of crop yield, weed burden and soil fertility. In particular, the paper presents the results from the second (winter beans) and third (winter oats) organic crops post conversion.

MATERIALS AND METHODS

Experimental Site and Design

Conversion to organic status began on 20 hectares of Bunny Park, Nottinghamshire (52^o, 52'N, 1^o, 07'W) in August 1999. Within the site 28 plots were established (each 12.5 x 30 m) which were sown with a red clover-ryegrass green manure on 5 September 1999. Seven conversion strategies were implemented and these were replicated four times in a randomised block design. Two of the conversion strategies were based on the previously sown red clover-ryegrass green manure (RCRC and CSRC, see Table 1), and five other strategies were implemented in March 2000 (Table 1). The abbreviations listed in Table 1 will be used from this point forward to denote each conversion strategy. Soil texture on the site ranged from sandy loam to sandy clay at a depth of 0-30 cm. To account for this variation, blocking was used (blocks 1 and 2 sandy loam and blocks 3 and 4 sandy clay). However, for simplicity, soil in blocks 1 and 2 will be referred to as sand, and blocks 3 and 4 as clay, throughout this paper. Conversion was completed in 2001 and a crop of organic wheat was planted over the entire experimental area. This was followed by the second (winter beans) and third (winter oats) organic crops which were the subject of the current experiment.

Table 1. Organic conversion strategies – Bunny Park.

Abbreviation	Conversion Strategy Year 1	Conversion Strategy Year 2
RCRC	Red clover-ryegrass	Red clover-ryegrass
VEVE	Vetch	Vetch-rye
CSRC	Red clover seed-ryegrass	Red clover
UWRC	Spring wheat under-sown with red clover	Red clover-ryegrass
OABE	Spring oats	Winter beans
WHBE	Spring wheat	Winter beans
UWBP	Spring wheat under-sown with red clover	Spring barley with pea intercrop

Combine yield

Crop yield was estimated on 19 August 2003 and 8 August 2004 using a plot combine harvester (Sampo Rosenlew 2010) on a previously un-sampled strip of the plot. The average area combined was 50.7 m^2 (minimum area 49 m^2) for winter beans and 60.6 m^2 for winter oats (minimum area 59.6 m^2). A sub-sample of the combine yield was immediately oven dried at 80–85^{o}C to determine moisture content. Additional samples were sieved to remove trash and both the trash and crop were weighed. Using this data the combine yield could be adjusted and a 'clean yield' calculated.

Soil sampling

Soil was sampled in September 2002, February and November 2003, and February and August 2004. Sampling was carried out using soil augers and measurements were taken throughout the depth of the profile from 0 to 90 cm. Six samples were taken from each plot in a W shape to ensure a fully representative sample was obtained and samples from the same horizons within a plot were bulked for analysis. Soil was then placed in cold storage before being sent to Natural Resource Management Ltd for nutrient analysis the following day.

Samples for soil structural assessment were taken in April 2004 on all 28 plots. Three replicates were taken from the top 5 cm of the 'A' horizon using hollow metal cylinders (7.5 cm diameter). These were then impregnated with approximately 200 ml of plaster of Paris (general grade) by positioning onto a funnel connected to a vacuum pump (Charles Austen Pumps Ltd). Plaster of Paris was then forced to pass through the soil sample and to remain in any soil pores whilst the excess was passed through the small holes in a lid at the base of the core. After drying for 48 hours the first few millimetres of soil at the top of the sample were skimmed off to expose the impregnated soil pores. Cores were then cut into four sections, each approximately 1 cm deep and photographed using an Olympus C3030 camera (image resolution 0.670 mm per pixel). The macro-porosity (pores > 210 µm) of each soil sample was determined using 'Image Tool' software and images were cropped prior to analysis to avoid edge effects.

Weed sampling

Weeds were recorded along two 30 m line transects per plot, each 2 m from the plot edge. The name of each weed species occurring along the transect line was recorded, together with the number of times that species was observed. Species composition and total number was monitored at five or six weekly intervals along the line transects from April to August 2003 and April to July 2004. The location of the transect lines was marked to allow them to be placed in exactly the same position on subsequent visits.

Statistical analysis

All experimental data was analysed using an analysis of variance (ANOVA) or regression analysis in Genstat 6.1/7 for Windows. Where appropriate, data was transformed prior to analysis to meet the assumption of homogeneity of variance.

RESULTS

Combine yield

Winter bean yields from VEVE, UWRC, UWBP and CSRC were significantly higher (P=0.02) than from WHBE and RCRC (Table 2). Winter oat yield showed a clear effect of conversion strategy ranging from 3.2 t ha^{-1} to 4.2 t ha^{-1} (P=0.01, Table 2). Yields from CSRC, UWRC and RCRC were significantly larger than those from OABE. In addition, winter oat yields from CSRC and UWRC were also significantly larger than those from WHBE. There was no significant effect of soil texture on either winter bean or winter oat combine yield.

Table 2. The effect of conversion strategy on winter bean and winter oat combine yield

Conversion Strategy	Winter bean yield (t ha^{-1}) at 14% moisture	Winter oat yield (t ha^{-1}) at 15% moisture
RCRC	2.8	3.8
VEVE	3.6	3.6
CSRC	3.4	4.2
UWRC	3.6	4.2
OABE	3.1	3.2
WHBE	2.8	3.3
UWBP	3.5	3.5
P Value	0.02	0.01
SED (12 df)	0.240	0.238

Soil fertility

At the start of the current experiment (September 2002) the clover-based strategies, RCRC, CSRC and UWRC, had the most soil mineral nitrogen (SMN) (P<0.01, Table 3). The highest values for SMN were recorded from the CSRC strategy in both February and November 2003 (winter beans). In February 2003 this was significantly different from that recorded in all the other conversion strategies (P<0.05). In February 2004 (winter oats) there was a trend for the more exploitative strategies, WHBE, OABE and UWBP to have lower levels of SMN (0-90 cm) although this was not significant (Table 3). However, after oats were harvested (August 2004) the CSRC, RCRC, UWRC and UWBP strategies had significantly more SMN than the OABE/WHBE strategies (P=0.011). There was no significant effect of soil texture on SMN on any of the five sampling dates.

SMN levels varied over time with the most SMN being recorded in November 2003. More SMN was recorded at the start of the current experiment than at the end. Moreover, the range of SMN values between conversion strategies was 22.6 kg N ha^{-1} in September 2002 but only 7 kg N ha^{-1} by August 2004.

Table 3. The effect of conversion strategy on soil mineral nitrogen, 0-90cm (kg N ha^{-1}).

Conversion strategy	Sep 02	Feb 03	Nov 03	Feb 04	Aug 04
RCRC	37.7	37.0	83.4	30.6	23.2
VEVE	23.0	35.0	74.2	32.9	19.9
CSRC	33.7	53.3	91.0	38.8	23.4
UWRC	33.5	38.6	90.4	38.6	22.3
OABE	15.1	26.8	71.0	25.2	16.4
WHBE	15.2	26.3	64.8	24.3	16.9
UWBP	19.2	33.2	79.4	25.5	21.4
Mean	25.3	35.7	79.2	30.8	20.5
P Value	< 0.01	< 0.01	0.03	0.15	0.01
SED (12 df)	4.36	3.55	7.25	6.26	1.89

Phosphorous levels increased from 2003 to 2004 in all conversion strategies with the exception of WHBE (P=0.02). Potassium levels also increased slightly over the same period (P=0.05). In neither year was there a significant effect of conversion strategy on soil phosphorus or potassium levels.

Soil organic matter (OM) levels did not vary significantly between conversion strategies in either 2003 or 2004. However, there was an overall non-significant decrease in the measured OM levels from 1.61% in 2003 to 1.02% in 2004.

There was no significant effect of conversion strategy on soil structure, as reflected by soil porosity and there was no significant difference in porosity between sand and clay soil.

Weed abundance

On 11 April, OABE and WHBE had significantly more weeds than either CSRC or UWRC (Table 4a; P=0.03). Furthermore, the number of weeds recorded from OABE and WHBE strategies was greater than in all five other strategies in May (P=0.001), July (P=0.007) and August 2003 (P=0.005). Transect data from each sampling date in 2004 also showed a significant effect of conversion strategy on weed number (Table 4b). On 26 April the WHBE strategy had more weeds than either the UWRC or VEVE strategies (P=0.037). Moreover, in both June and July 2004 (P<0.001) there were significantly more weeds recorded along transect lines from the WHBE/OABE strategies (>170) than any other strategy (<140).

Table 4. The effect of conversion strategy on the mean number of weeds along a 30 m transect line within a) the winter bean crop, 2003 and b) the winter oat crop, 2004 (transformed data also presented for analysis purposes).

(a)

	11-Apr		27-May		11-Jul		06-Aug	
Conversion strategy	**Weed no.**	**√weed no.**	**Weed no.**	**√weed no.**	**Weed no.**	**√weed no.**	**Weed no.**	**√weed no.**
RCRC	35	5.7	108	10.2	99	9.9	100	10.0
VEVE	35	5.7	100	9.9	93	9.6	96	9.7
CSRC	26	5.0	109	10.4	94	9.7	91	9.5
UWRC	18	4.1	98	9.8	101	10.0	91	9.5
OABE	65	7.6	152	12.2	139	11.6	119	10.9
WHBE	57	7.5	149	12.1	137	11.6	119	10.9
UWBP	43	6.3	114	10.6	99	9.9	89	9.4
P Value		0.03		0.001		0.007		0.005
SED (12df)		0.95		0.52		0.54		0.39

(b)

	26-Apr		10-Jun		7-Jul	
Conversion strategy	**Weed no.**	**√weed no.**	**Weed no.**	**√weed no.**	**Weed no.**	**√weed no.**
RCRC	98	9.8	110	10.4	90	9.1
VEVE	87	9.3	122	11.0	118	10.7
CSRC	114	10.5	139	11.6	108	10.2
UWRC	83	9.1	112	10.5	96	9.7
OABE	103	10.1	191	13.7	191	13.6
WHBE	116	10.8	172	13.1	179	13.3
UWBP	99	9.9	124	11.1	114	10.6
P Value		0.037		0.001		0.001
SED (12df)		0.48		0.51		0.50

There was a highly significant relationship ($P<0.001$) between weed number in August and winter bean yield (Figure 1). Linear regression with groups showed that crops with the same number of weeds produced greater yields on sandy soil than on clay soil. In the oat crop, SMN in November together with weed abundance in April, accounted for 72% of the variation in yield (Equation 1)

Equation 1: $Y = 4.196 - 0.192 \times \text{sqrt (weed no.)} + 0.01837 \times \text{SMN}$ ($P<0.001$)

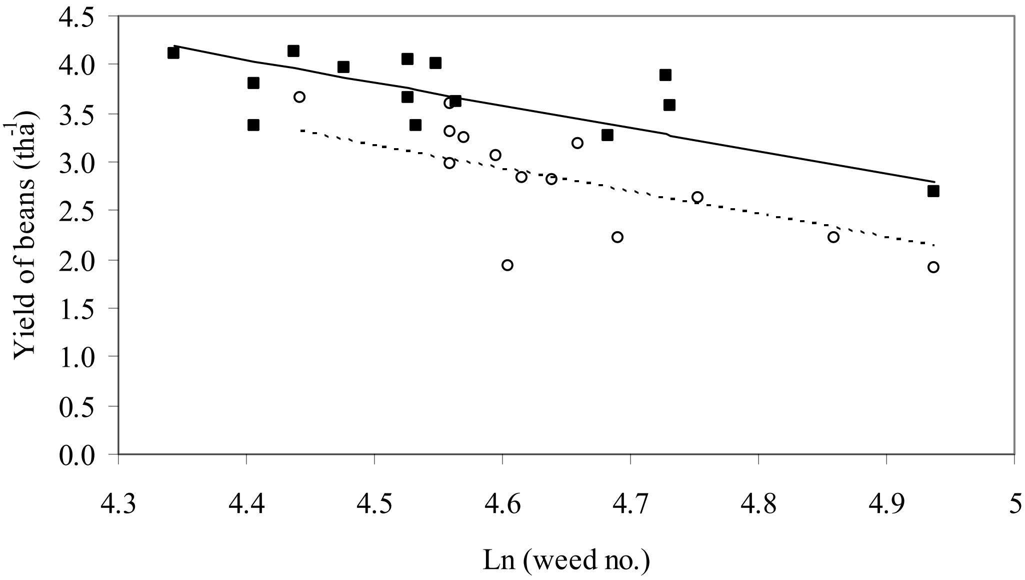

Figure 1. Linear regression of bean yield on ln (weed number) per line transect on 6 August. ■ sand y = 13.73 -2.347x ln(weed no.); ○ clay y=14.38-2.347x ln(weed no.). R^2=0.70

Weed species

A total of 26 different species were identified from line transects in 2003 and 24 species in 2004 (Table 5). However, although the weed population on the site was fairly diverse it was dominated by a few species. Species with the largest biomass in the winter bean crop were ivy-leaved speedwell (*Veronica hederifolia*), scentless mayweed (*Tripleurospermum inodorum*), knotgrass (*Polygonum aviculare*), creeping thistle (*Cirsium arvense*), volunteer cereals (*Triticum aestivum* and *Avena fatua*), fat hen (*Chenopodium album*) and orache (*Atriplex patula*). During the winter oat crop the dominant weed species were volunteer beans (*Vicia faba*), mayweed, creeping thistle and poppy (*Papaver rhoeas*).

Table 5. Weed species recorded from transect lines 2003 and 2004.

A. Annual. B. Biennial. P. Perennial. + Present. - Absent.

English common name	Botanical name	Life Cycle	2003				2004		
			14 Apr	27 May	11 Jul	6 Aug	26 Apr	10 Jun	7 Jul
Annual meadow grass	*Poa annua*	A	+	+	+	+	+	+	+
Bugloss	*Anchusa arvensis*	A/B	-	+	+	+	+	+	+
Buttercup	*Ranunculus repens*	P	+	-	-	+	-	-	-
Chickweed	*Stellaria media*	A	+	+	+	+	+	+	+
Cleavers	*Galium aparine*	A	-	-	-	-	-	-	+
Colts foot	*Tussilago farfara*	P	-	-	-	-	+	+	+
Common speedwell	*Veronica officinalis*	P	+	+	+	+	+	+	+
Cranesbill	*Geranium pratense*	P	-	+	-	+	-	-	-
Creeping thistle	*Cirsium arvense*	P	+	+	+	+	+	+	+
Dandelion	*Taraxacum officinale*	P	+	+	+	+	+	+	+
Dock	*Rumex crispus*	P	+	+	+	+	+	+	+
Fat hen	*Chenopodium album*	A	+	+	+	+	-	+	+
Field bindweed	*Convolvulus arvensis*	P	+	+	+	+	+	+	+
Field pansy	*Viola arvensis*	A	+	+	+	+	+	+	+
Fool's parsley	*Aethusa cynapium*	A/B	+	+	+	+	+	+	+
Groundsel	*Senecio vulgaris*	A	-	+	+	+	+	-	+
Ivy leaved speedwell	*Veronica hederifolia*	A	+	+	-	-	+	+	-
Knotgrass	*Polygonum aviculare*	A	+	+	+	+	+	+	+
Orache	*Atriplex patula*	A	-	+	+	+	-	-	-
Perennial sowthistle	*Sonchus arvensis*	P	+	+	+	+	-	-	-
Poppy	*Papaver rhoeas*	A	+	+	+	+	+	+	+
Red clover	*Trifolium pratense*	P	+	+	+	+	+	+	+
Red dead nettle	*Lamium purpureum*	A	-	-	-	-	+	-	+
Rosebay willowherb	*Chamaenerion angustifolium*	P	+	+	+	+	+	+	+
Ryegrass	*Lolium perenne*	A/B	-	-	-	-	-	-	-
Scentless mayweed	*Tripleurospermum inodorum*	A	+	+	+	+	+	+	+
Shepherd's purse	*Capsella bursa-pastoris*	A	+	-	-	-	+	-	-
Spurrey	*Spergula arvensis*	A	-	-	+	+	-	+	+
Vetch	*Vicia sativa*	A	-	-	-	-	-	+	+
Volunteer wheat	*Triticum aestivum*	A	+	+	+	+	-	-	-
Wild oat	*Avena fatua*	A	-	-	+	+	-	-	-

DISCUSSION

Crop yield

The OABE and WHBE strategies had the lowest yields in both the winter bean and winter oat crops. These low yielding strategies had the highest weed numbers and also the lowest SMN values. Regression analysis showed that the variable which best explained winter bean yield was the number of weeds along a 30 m line transect in August. Within the oat crop, weed abundance in April, together with SMN (November) explained 72% of the variation in yield. RCRC had the same average bean yield as WHBE, but gave the third highest yield of oats. This underlies the importance of weed competition in determining bean yield, whereas in oats SMN was also a yield determining factor – and RCRC strategy always had amongst the largest SMN levels.

Weed abundance

As discussed above, weed abundance was an important influence on crop yield in both the winter bean and winter oat crops. Thus, weed dynamics during the conversion period can have important implications for weed burden in the subsequent rotation (Albrecht and Sommer, 1998). Huxham (2003) measured differences in weed burden during the conversion period with the clover-based strategies having significantly less weed dry matter than, for example, UWBP. Red clover is a very competitive plant which forms a dense mat leaving little ground in which weeds can establish and germinate (Leake, 2000). By the end of the second year of conversion, significant differences in weed biomass were recorded with a tendency for the more exploitative strategies, OABE and WHBE, to have a greater weed biomass. This may have resulted in more weed seeds entering the seed bank than from the clover-based strategies; a finding reinforced by Younie *et al*. (2002) who noted that rotations with a higher proportion of grass-clover leys had consistently smaller weed seed banks than those with a higher proportion of cereal and vegetable crops. However, although significant differences in weed abundance were observed in the current study, significant differences in weed biomass were not. One explanation for the lack of significant differences in weed biomass is the spatially heterogeneous nature of weed distribution, together with a small number of large individual weeds. Large weeds, such as docks, occurred infrequently but had a large impact on weed biomass and it is possible that an increase in the number or size of the samples taken may have improved the likelihood of detecting significant differences in weed abundance between strategies.

A fairly diverse weed population was recorded in both the winter bean and winter oat crops with 26 weed species identified in 2003 and 24 in 2004. Huxham (2003) recorded 19 weed species in the second year of conversion and 26 species in the organic wheat crop. Hence, there is a suggestion that the number of weed species have increased since conversion but then remained at a consistent level. In contrast Davies *et al*., (1997) reported that there was no increase in weed species during the conversion period. Nevertheless, despite the large number of species recorded in the current experiment a small number of weed types were dominant in 2003 and 2004.

In common with other studies of stockless organic systems, creeping thistle was persistent (Cormack, 1999; Leake, 1996; Welsh *et al.,* 2002). The OABE and WHBE strategies tended to have a greater biomass of creeping thistle throughout the winter bean and winter oat crops. Once established, thistle spread is primarily vegetative and as a result thistle distribution is often patchy. Thistle growth may have been facilitated in the OABE/WHBE strategies during the conversion period when both cereal and bean crops had poor establishment. In addition, cultivations were more frequent during the conversion period in these strategies than in the clover-based strategies. The resulting soil disturbance would have provided ideal conditions for thistle seedling establishment. Thistles are extremely resilient and experiments have shown that 19-day-old seedlings with two true leaves were able to re-sprout after removal of top growth (Wilson, 1979).

Scentless mayweed is one of the most abundant annual weeds of arable land in Britain. This was reflected in the current study where mayweed was one of the dominant weed species in both years. For example, mayweed made up, on average, over 30% of the weed biomass recorded in August 2003. A good correlation has been previously noted between seed number and plant dry weight in this species suggesting that uncontrolled, the plant has a vast capacity to spread (Lutman, 2002). Early season harrowing failed to control this species in either the winter bean or winter oat crops. It also became well established during the organic wheat crop when it was postulated by Huxham (2003) that lack of competition, in some areas of the crop, allowed the weed to become established. Fat hen and knotgrass were common in the winter bean crop but rarely noted in the winter oat crop. In contrast, poppy was much more frequently seen in the oat crop being one of the four commonest species. The dominant weed species in the winter oat crop was volunteer bean, which often comprised more than 50% by weight of a weed sample.

<u>Soil mineral nitrogen</u>

Soil mineral nitrogen throughout the experiment was highest in the clover-based strategies and lowest in OABE and WHBE. The magnitude of the SMN values changed, but the ranking stayed broadly similar from before the bean crop was sown until after the oats were harvested.

Following organic wheat harvest, least nitrogen remained in crop and weed residues in WHBE and OABE strategies and most in UWRC and CSRC (Huxham, 2003). In broad agreement with those findings, SMN measurements at the beginning of the current study, i.e. at the end of the organic winter wheat crop and prior to the winter bean crop, showed that there was significantly more SMN in RCRC, CSRC and UWRC than in the other four strategies with the lowest levels being recorded in the OABE and WHBE strategies.

As expected, SMN had no relationship with bean yield in the current study with weed abundance alone accounting for 70% of the variation in yield. As beans are leguminous and thus fix their own N the levels of SMN would be expected to remain similar or increase slightly throughout the bean crop. Indeed, the average SMN increased from 35.7 to 79.2 kg ha^{-1} during the bean crop and the ranking between strategies stayed broadly the same. Moreover, the strategies with the highest levels of SMN at the end of the bean season were those that had the most nitrogen returned in crop and weed residues at the end of the wheat crop and *vice versa*. Thus as the bean crop was fixing N_2, and not relying on SMN for nitrogen input, the effects of wheat residues were able to persist.

Differences in SMN seem to have persisted into the organic rotation through differences in the mineralisation rates of the green manures and crop residues added in the conversion period. Moreover, it is expected that nitrogen in roots mineralises more slowly than in shoots due to a higher C to N ratio in the roots. This may be of importance for the conservation and carry-over of nitrogen to the next crop in the rotation. Hence, crops which accumulate large amounts of nitrogen in the shoots, may mineralise more nitrogen during the same period than if they accumulate relatively more in the roots. Kirchmann (1988) reported that 35% of the total N in red clover was contained within the root system. Hence, the shoot and root components of red clover may mineralise at different rates and as a consequence provide N over a sustained period. The first organic crop did not show a direct effect of SMN on yield levels (Huxham *et al*., 2005) but the residues added to the soil at the end of that crop did have higher levels of N from the clover-based strategies. As would have been expected the bean crop showed little response to SMN. However, at the end of the bean crop there was still more SMN in the clover-based strategies than in the more exploitative strategies. In the final crop, winter oats, the SMN level coupled with weed abundance was an important determinant of yield.

<u>Soil structure</u>

Huxham *et al*. (2005) concluded that soil structure interacted with soil texture to influence plant establishment, which was in turn the main determinant of yield for the first organic crop (winter wheat). However, determination of macro-porosity (pores > 210 μm) by image analysis in February 2004 showed no significant differences in this component of soil structure. So, the effects of conversion strategy on soil structure did not persist beyond the first organic crop.

<u>Other indicators of soil fertility</u>

Other nutrients such as phosphorus (P) and potassium (K) are also important for optimum crop yields. Both may be exported in harvested grain but substantial amounts of potassium may remain in the straw. However, for both of these nutrients no significant differences as a result of the previous conversion strategies were noted in either the winter bean or winter oat crop. However, the level of both nutrients increased from 2003 to 2004. In agreement with these findings Bulson *et al*. (1996) also recorded increased P and K levels over the course of an eight-year stockless organic field experiment on a clay loam. In contrast, Cormack (1999) measured a decline in phosphorus levels and a relatively stable level of potassium in a stockless field experiment on a silty clay loam.

Increases in soil organic matter under organic management have been widely reported (Clark *et al*., 1998). However, many studies have focussed on sites that are either part of a stocked system or receive regular additions of animal manures. As a consequence, the results from these studies are not directly comparable with the stockless rotation used in this study. Organic matter levels showed a relatively rapid decrease during the current study, from 1.61% in 2003 to 1.02% in 2004 although this was not significant. This is a fall from the organic matter level reported at the end of the wheat crop of 2.27% (Huxham, 2003). Huxham (2003) also reported higher organic matter levels than from the current study in the conversion period of 1.95% (February 2000), 2.32% (February 2001) and 2.12% (February 2002). At no point in either the current study or the previous study by Huxham (2003) did organic matter levels vary significantly between conversion strategies. The fairly large changes in organic matter levels are surprising as studies on the transition from conventional to organic or low input practices have shown that changes in soil organic matter typically occur slowly and can take several years to detect. For example, soil organic matter increases of only a few tenths of a percent have been reported after ten years of organic management (Wander *et al*., 1994). In contrast, Bulson *et al*. (1996) reported a decline in organic matter levels from a stockless field trial from a level of about 3.1% to around 2.5% over an eight-year period. In addition, Cormack (1999) reported that organic matter levels stabilised at around 2.5% in another stockless field trial, also over an eight-year period. Hence, other stockless rotations have seen a stabilisation of organic matter levels at around 2.5%. Thus, the rapid decline in organic matter levels from the end of the winter wheat crop (2.27%) to the end of the winter oat crop

(1.02%), a reduction of 1.25% over a two-year period was somewhat unusual and clearly unsustainable if the decline continues at this rate. As the concentration of organic matter in soils is primarily related to climate, soil texture and soil drainage, changes in any or all of these factors may have influenced the reduction in organic matter levels. However, crop rotation and management usually play a smaller but important role (Shepherd, Harrison and Webb, 2002). The reasons for the rapid decline in the percentage of organic matter are unclear but some possible causes have been outlined above.

CONCLUSIONS

The results from this study indicate that the choice of conversion crop has important longer-term implications. More exploitative conversion strategies, i.e. those with a higher proportion of cash cropping, had an increased weed burden and decreased levels of soil mineral nitrogen. Differences in weed burden were suggested to have originated from weed seed bank increases during the conversion period. The poor establishment of both cereals and beans during the conversion period, which left bare ground for weed germination, also facilitated weed establishment. Moreover, strategies such as OABE and WHBE had more cultivations than the clover-based strategies, which would have caused soil disturbance and again an increase in weed numbers. As was the case with weed abundance, differences in SMN levels have been suggested to originate in the conversion period. Of the seven conversion strategies, those with a green manure component added more nitrogen to the soil than those with the emphasis on cash cropping. In addition, differences in residue composition may have led to differences in the mineralisation/immobilisation turnover amongst strategies. Weed burden had an important influence on the yield on both winter beans and winter oats. In contrast, as would have been expected, soil mineral nitrogen had no effect on the yield of winter beans but was an important determinant of winter oat yield.

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Part 2. The Economic Legacy of Stockless Organic Conversion Strategies

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Abstract

Expansion of the area of organic and in-conversion land has increased in recent years, albeit at a slower pace than that achieved in the late 1990s. Despite this, organic cereal production represents only 1.4% of total cereal production and accounts for approximately 20% of the UK demand for organic cereals. This paper explores the economic legacy of seven stockless organic conversion strategies, focusing upon the impact of the conversion strategies on the second (bean) and third (oat) crops, but also considering the economics of the two-year conversion period and the first organic crop (wheat) in making strategy recommendations to growers considering conversion. Gross margin results indicate conversion strategies containing fertility building phases provide the highest overall gross margin returns, with the clover-seed – red-clover ryegrass strategy returning an average annual gross margin in the absence of subsidies of £459 ha^{-1}; the second best strategy being the two-year red-clover ryegrass strategy providing an annual average gross margin of £357 ha^{-1}. By contrast the wheat-bean strategy provides the lowest gross margin of £274 ha^{-1}. The influence of the factors that drive this economic performance, as measured through the productivity of land, are captured through the estimation of a land quality index (LQI) using regression analysis. Both a measured LQI based upon actual financial returns and a predicted LQI based upon the estimated regressions are provided and explain the overall quality of land, with respect to its productive capacity, as measured over the second and third organic crops. Economic input-output measures of average value product and marginal value product are also derived from the predicted LQI. For a risk-averse grower, the recommended conversion strategy is the two-year red-clover ryegrass strategy based upon the overall financial return this provides and the agronomic attributes associated with this conversion strategy.

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1. Introduction

Since March 2003 there has been an increase in the total area of organic and in-conversion land in England from approximately 251,800 ha to 258,930 ha in January 2004 (DEFRA, 2004b). This is a much slower expansion than that noted in previous years and reflects uncertainties concerning the organic market and the implementation of the Common Agricultural Policy (CAP) reform (Lampkin, Measures and Padel, 2004). Of the 2004 figure, 36,904 ha (14%) was in-conversion and 222,026 ha (86%) was fully organic. Whilst the fully organic area has increased by 21% the area of land in-conversion has fallen by 46% indicating a decline in the land area entering organic production. Despite the increase in fully organic land, this still only accounts for approximately 2.8% of all English farmland. Furthermore, even though there have been large increases in the area under organic cereals (21%), from March 2003 to January 2004, this still only accounts for 1.4% of the land currently used in England for cereal production. Due to favourable climatic conditions, the 2003 cereal harvest was good and 50% (compared with 20% in the previous year) of the UK demand for organic cereals was met by domestic production (Lampkin *et al.,* 2004; Soil Association, 2002). However, this was an atypical year and, as such, there is still a large unmet demand for organic cereals and thus potential for continued growth in the organic sector.

Government support for both conventional and organic agriculture has recently undergone a period of change as a result of modifications to the CAP. At the start of 2005, support payments were decoupled from production when the Single Farm Payment (SFP) replaced Arable Area Payments and other direct support payments. As a result farmers may have a greater incentive to be more market-led in their production as the SFP will provide a guaranteed income irrespective of crop choice. The contribution that organic farming can make towards the government's aim of sustainable land management and high standards of environmental performance was recognised in the 2002 Strategy for Sustainable Farming and Food (DEFRA, 2002). As a result, government support, which was until recently administered through the Organic Farming Scheme (OFS), was amended in order to encourage UK farmers to undergo conversion from conventional to organic agriculture. The OFS provided financial support for the first five years of conversion (£225 ha^{-1} in year one, £135 ha^{-1} in year two and £30 ha^{-1} in years three to five) and maintenance payments (£30 ha^{-1}) for the first five years of organic production. In addition, lump sum payments of £300, £200 and £100 per farm in year one, two and three respectively were available towards the initial cost of advice and training when setting up an organic unit. However, the OFS was closed on 3 March 2005 when the organic strand of the Entry-Level Stewardship (OELS) was introduced with conversion payments of £175 ha^{-1} per year for two years, plus ongoing payments of £60 ha^{-1}. Different payments rates apply in other parts of the UK (see ABC, 2005). Conversion aid is also available as a supplement or top up to the main OELS payment on a limited number of land types (improved land and top fruit orchards). Although the OELS has replaced the OFS, agreements made under the OFS prior to the introduction of the OELS will continue to be honoured.

1.1 The Economics of Conversion

The majority of conventional arable production in England occurs in stockless systems in the eastern counties. In contrast, organic arable production tends to occur in central and southern England often on marginal cereal land (Ilbery, Holloway and Arber, 1999). For conventional farms the uptake of organic farming has been severely limited by the capital investment required to introduce a livestock enterprise as part of a typical organic mixed system (Bulson *et al.*, 1996). This has provided the incentive for the development of stockless organic systems. In stockless systems the rotation will rarely include a long ley phase to provide a balance between fertility building and exploitative arable crops. Instead, short-term leguminous green manures are frequently used to accumulate nitrogen for the subsequent rotation. However, both the short and longer-term legacy of the conversion period is important. In particular, the effects on the following organic crop yields, and as a result organic gross margins, are of crucial importance to those considering organic conversion and examining alternative conversion cropping plans during this conversion period.

Evidence from experiments in the UK to date suggests that stockless organic production is economically viable (Bulson *et al.*, 1996; Cormack, 1999). Bulson *et al.* (1996) noted that the economic performance from an organic rotation incorporating potatoes and combinable crops would compare favourably with gross margins achieved under mixed organic or conventional arable systems (Bulson *et al.*, 1996). Moreover, extrapolating data from experiments to farm scale, Cormack (1999) reported that a simple organic arable rotation compared favourably with a conventional rotation.

Both long-term experiments outlined above included the typical two-year red clover green manure conversion period. In contrast, Huxham *et al.* (2005) investigated the effects of seven conversion strategies (Table 1) on a subsequent organic winter wheat crop at Bunny, Nottinghamshire. The design of this experiment allowed a comparison between the traditional red clover green manure strategy and a wide range of other strategies to be undertaken.

Table 1. The conversion strategies studied by Huxham *et al.* (2004; 2005).

Abbreviation	Conversion Strategy Year 1	Conversion Strategy Year 2
RCRC	Red clover/ryegrass	Red clover/ryegrass
VEVE	Vetch	Vetch/rye
CSRC	Red clover seed/ryegrass	Red clover
UWRC	Spring wheat under-sown with red clover	Red clover/ryegrass
OABE	Spring oats	Winter beans
WHBE	Spring wheat	Winter beans
UWBP	Spring wheat under-sown with red clover	Spring barley with pea intercrop

Gross margin analysis of the seven conversion strategies was carried out in the presence and absence of AAP and OFS payments (Huxham, *et al.,* 2004). Averaged over the three-year period the clover seed - red clover strategy (CSRC) had the highest mean annual gross margin of £696 ha^{-1} as a result of the good clover seed price (£1000 t^{-1}) and high organic wheat yield although this was highly dependent on securing a market for the clover seed. The RCRC had the second highest gross margin (£632 ha^{-1}) due to low variable costs during the conversion period coupled with a high organic wheat yield. Results also suggested that the increased income during conversion from strategies including commercial cropping (OABE, WHBE and UWBP strategies) was not enough to offset the subsequent lower income that was derived from the first organic crop following these strategies.

The prospects for stockless organic farming seem promising although the conversion period is often a time of reduced income where losses are expected (Lampkin, 1994; O'Riordan and Cobb, 2001). However, recent studies (e.g. Huxham, 2003; Huxham *et al*., 2004; 2005) have been limited in their assessment of the longer term effects of conversion on the viability of organic systems. Hence, knowledge of the legacy of alternative conversion strategies on the economics of subsequent cropping is vital if stockless systems and possible conversion routes to organic status are to be successfully evaluated.

In addition to analysing the economics of conversion on future production, understanding the underlying factors driving this economic performance is important. One way to capture the effect of different conversion strategies on future production is to measure the productive capacity of the system as influenced by a range of possible factors; crop yield may be reduced through weed competition, inadequate supplies of essential nutrients such as N, P and K, soil fertility (e.g. low levels of organic matter) and poor soil structure. Organic systems differ from conventional systems in that a 'quick fix' is rarely possible. Weeds cannot be simply eradicated by the use of herbicides and nutrients cannot be quickly boosted by the use of artificial fertilisers. Instead an organic system must rely on carefully managed, well-planned rotations and cultivations to ensure crops yield to their full potential.

A methodological approach to objectively define the productive capacity of any management system is through the use of an appropriate indexing system that captures the 'quality' of the land. This can allow the influences of importance factors on the system such as those outlined above to be determined. Indices can be valuable management tools offering the opportunity to compare disparate systems over both the short and longer-term. Placing a value on land or soil, in regard to a specific function, purpose or use, leads to this concept of 'quality'. However, given the fact that 'quality' will vary depending on the desired product from the use of land, there is little agreement on how it should be defined. For example, soil quality has been described as a combination of the physical, chemical and biological properties that contribute to soil function (Knoepp *et al.*, 2000). It has also been defined as 'the capacity of a specific kind of soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation' (Karlen *et al.*, 1997). However, at present there is no consensus on a definitive data set for soil quality monitoring, nor consensus on how the indicators should be interpreted (Schipper & Sparling, 2000). Attributes that are sensitive to management practices are most desirable as indicators. For example, it has been suggested that these measurable soil attributes are: soil depth, organic matter, respiration, aggregation, texture, bulk density, infiltration, nutrient availability and retention capacity (Arshad & Martin, 2002). However, this offers only one example. More generally, once the management goals have been identified quality indexing will usually involve three main steps (Andrews *et al.*, 2002); the first will be to choose appropriate indicators of a minimum data set, the second to transform the selected indicator scores and finally the indicator scores must be combined into an index. The selection of a minimum data set has traditionally relied on expert opinion to select the appropriate components. However, the question of what variables to include in any index may be simplified and more rigorously assessed by statistical methods.

This paper examines the economic effects of seven conversion strategies over the two years of conversion and the first three years of organic production. Gross margins are presented for the two-year conversion period, the three-year post conversion organic crops and for the entire five-year period. Comparisons with conventional gross margins are also presented. The paper proceeds to present a methodology defining land quality in relation to crop output to produce a land quality index. The results of this analysis are then used to determine further input-output measures. Finally, in light of the gross margin analysis, land quality index results and economic input-output measures, stockless organic conversion strategy recommendations are made.

2. Gross Margin Analysis: Conversion followed by Three Organic Crops

Building on the work of Huxham *et al.* (2004; 2005) this study aimed to identify the longer-term effect of seven different conversion strategies specifically examining the second and third organic crops, but also accounting for the conversion period and the first organic crop. Organic conversion began in August 1999 on 20 hectares of Bunny Park Farm, Nottinghamshire. Within the site a field experiment was established consisting of 28 experimental plots each measuring 12.5 m x 30 m. Seven conversion strategies were implemented (Table 1, presented earlier) and these were replicated four times in a randomised block design. Blocking was used to account for the variation in soil texture, which ranged from sandy loam to sandy clay. Post conversion the rotation was winter wheat, winter beans and winter oats.

The design of the overall experiment allowed a comparison between the traditional red clover green manure strategy and a wide range of other strategies to be undertaken. However, several strategies were included that would not have qualified as legitimate conversion strategies at the start of the conversion period (1999) due to their lack of fertility building cropping (OABE, WHBE and UWBP). These strategies included commercial cropping to generate income during conversion and as a result to reduce the financial pressure associated with this period. However, these strategies could result in reduced soil fertility, poorer yields and longer-term financial losses. Huxham *et al.,* (2004; 2005) considered the two year conversion period and the first organic crop. This current study focused upon the second and third organic crops (beans and oats respectively). However, in order to examine the effects of the conversion strategies in context, we present gross margin data covering the entire five-year period. Therefore, gross margins have been calculated for (i) the second and third organic crops, (ii) the two-year conversion period plus the first organic crop, and (iii) the complete five-year period (Tables 2-4 respectively). Crop prices (winter wheat £185 t^{-1}, winter beans £200 $t^{-1}$and winter oats £160 t^{-1}) were taken from the 2002/03 Organic Farm Management Handbook (Lampkin *et al*., 2002).

The average gross margin for the winter bean crop was £543 ha^{-1} with a range of £448 ha^{-1} from the RCRC strategy to £616 ha^{-1} from the VEVE strategy (Table 2). This coincides with Lampkin *et al*. (2002) who reported an average gross margin for winter beans without subsidies of £543 ha^{-1}. In the winter oat crop the average gross margin was slightly lower at £515 ha^{-1} with a range of £445 ha^{-1} from the OABE strategy to £592 ha^{-1} in both CSRC and UWRC strategies (Table 2). This is slightly higher than the average winter oat gross margin excluding subsidies of £493 ha^{-1} reported by Lampkin *et al*. (2002). The gross margins for the bean and oat crops showed that strategies with a fertility building conversion period had larger gross margins than those with a more exploitative conversion period (Table 2). For example, UWRC had the highest gross margin of £600 ha^{-1}, whilst the WHBE had the lowest gross margin of only £460 ha^{-1}. However, the traditional conversion strategy of RCRC was only ranked fifth in terms of gross margin when the joint performance of the second and third organic crops was considered in isolation of the conversion period and the first organic crop.

Table 2. Annual average gross margins for the second and third organic crops

	Bean GM £ ha^{-1}	Oat GM £ ha^{-1}	Annual average GM, 2nd & 3rd organic crops £ ha^{-1}	Strategy rank 2nd & 3rd organic crops £ ha^{-1}
RCRC	448	528	488	5
VEVE	616	499	558	**3**
CSRC	562	592	577	**2**
UWRC	608	592	600	**1**
OABE	512	445	479	6
WHBE	460	459	460	7
UWBP	592	493	543	4
Mean	**543**	**515**	**529**	

In order to test the robustness of the strategy rankings, and make it easier to recommend particular strategies, sensitivity analysis was carried out on the two organic crops within the current study (data not presented). Sensitivity analysis to both changes in yield (a 1 s.d. increase or decrease about the experimental yield) and crop price (a reduction or increase in price of both 20 or 50%) were undertaken. Both variation in yield and price will impact on the overall economic performance and as a result strategy ranking an as such it is necessary to test the robustness of the results through sensitivity analysis. The top three ranked strategies over the combined output of beans and oats (UWRC, CSRC and VEVE) remained the top three under all yield sensitivity scenarios. Changes in crop prices also had minimal effect on the strategy ranking. Only when oat price was reduced by 50% of the original price did any change in the order of strategy ranking occur (resulting in strategy rankings of UWRC, VEVE and CSRC).

Gross margins were also calculated for the three post-conversion crops of wheat, beans and oats (Table 3). The top ranked strategies (CSRC and UWRC both £633 ha^{-1}) were those with a clover strategy containing red clover. Moreover, the RCRC strategy was ranked in third place, having a gross margin of £620 ha^{-1}, only slightly less than that of the other clover-based strategies. As previously noted, the WHBE strategy was ranked in last place.

Table 3. Annual average gross margins for the three-year organic rotation

	*Wheat GM £ ha^{-1}	Bean GM £ ha^{-1}	Oat GM £ ha^{-1}	*Annual average GM, 3 organic crops £ ha^{-1}	Strategy rank 3 organic crops £ ha^{-1}
RCRC	884	448	528	620	**3**
VEVE	551	616	499	555	4
CSRC	745	562	592	633	**1**
UWRC	698	608	592	633	**1**
OABE	533	512	445	497	6
WHBE	478	460	459	466	7
UWBP	430	592	493	505	5
Mean	**617**	**543**	**515**	**558**	

* GM data from conversion period and first organic crop is drawn from Huxham (2003). Data presented in the absence of subsidies.

Turning to consider the performance of the strategies over the five-year period, the average overall gross margin for the five-year period was £331 ha^{-1} with a range of £274 ha^{-1} (WHBE) to £459 ha^{-1} (CSRC) (Table 4). The strategies with the best gross margins over the five-year period were the three clover-based strategies of, in order, CSRC, RCRC and UWRC. Only the CSRC had an average gross margin of over £400 ha^{-1}, although UWRC, RCRC and OABE had average gross margins of over £300 ha^{-1}. CSRC had an average gross margin more than £100 higher than any other strategy, helped by the fact that it was one of only two strategies to have a positive gross margin for the conversion period. In contrast, the strategies with more exploitative conversion crops had lower annual average gross margins for the five-year period, albeit that OABE was ranked above the VEVE strategy. Over the five-year period this study indicates an average gross margin very similar to that reported by Lampkin *et al.* (2002); according to these authors a typical 240 ha stockless organic farm will have a gross margin without subsidies of £338 ha^{-1} compared with £331 ha^{-1} reported here. The six-year rotation in that case was two years red clover green manure, followed by winter wheat or potatoes, winter oats, field beans and spring wheat or barley.

Table 4. Annual average gross margins for the two-year conversion period and the three-year organic rotation.

	*Annual average GM conversion period £ ha^{-1}	Annual average GM, 3 organic crops £ ha^{-1}	Annual average GM, conversion period & 3 organic crops £ ha^{-1}	Strategy rank conversion period & 3 organic crops £ ha^{-1}
RCRC	-39	620	357	**2**
VEVE	-106	555	291	5
CSRC	199	633	459	**1**
UWRC	-70	633	352	**3**
OABE	29	497	310	4
WHBE	-15	466	274	7
UWBP	-66	505	277	6
Mean	**-10**	**558**	**331**	

* GM data from conversion period and first organic crop is drawn from Huxham (2003). Data presented in the absence of subsidies.

In order to assess the average financial performance of the three organic crops in comparison to other organic systems and to conventional production, the average gross margin (without subsidies) for the winter wheat, winter beans and winter oat crops was compared with the average gross margin from a typical organic and conventional system (Table 5) (Lampkin *et al.*, 2002; Nix, 2002). Of the three systems the conventional system always had the lowest gross margin; driven largely from the difference in the price for organic beans (£200 t^{-1}) and conventional beans (£87.50 t^{-1}) despite similar yields between organic and conventional production. Note however that these results present the financial assessment of the individual crops and as such do not account for the lack of income during the fertility building year in an organic system in comparison to the productive ability of a conventional system.

Table 5. A comparison of gross margins from the current experiment with the organic and conventional average for three crops (without subsidies)

	*Average wheat GM £ ha^{-1}	Average bean GM £ ha^{-1}	Average oat GM £ ha^{-1}
Current experiment	617	543	515
Organic average	595	543	493
Conventional average	315	190	295

3. Land Quality and Influence on Output

A second aim of this paper is to develop a methodology for explaining land quality as a function of factors that affect the productive capacity of land and to empirically test this methodology. The crop yield and subsequent revenue from any area of land may be considered as the output from that land, and is directly influenced by land quality. The productive capacity of land is a function of numerous factors. One way to explain the influence of such multiple independent factors is through the use of multiple regression analysis. This section details the use of multiple regression in developing the methodology to measure land quality, placing this in the context of the financial returns achieved from this crop production process.

Crop yield was used as the most objective proxy for land quality, being, in relation to the objective of growers, the most appropriate measure of productive capacity. Building upon this, the calculation of an objective value of land quality was derived through the construction of a land quality index (LQI) based upon the monetary value of yield produced. In developing the LQI, data collected in the course of each field season was used and linked to the monetary value of the crop yield. This measure of land quality can be calculated solely on the basis of output. However, such a calculation in itself will not explain the impact of individual properties of the land (e.g. weed burden) on its productive capacity. Thus, to explain the influence of these factors, multiple regression analysis was undertaken. In undertaking the regression analysis that sought to explain variation in crop yield, it was not necessary to use all the recorded agronomic variables and a meaningful minimum data set was determined. However, careful selection of the variables to be included in the minimum data set was essential to ensure the regression remained robust.

3.1 Output (£ ha^{-1}) over Two Organic Crops

As noted above, this study specifically examined the influence of conversion strategies on the second and third organic crops. The initial process in determining land quality to capture the productive ability of the land for these two crops, was to calculate the output (£ ha^{-1}) for the two organic crops of winter beans and winter oats (Table 6). This revealed that the top three strategies were UWRC, CSRC and VEVE. Total output over the two-year period varied from £1102 ha^{-1} (WHBE) to £1382 ha^{-1} (UWRC). Subsequently, the analysis seeks to estimate the influence of independent factors on output through regression analysis.

Table 6. Output (£ ha^{-1}) of two organic crops with ranking according to output

Conversion strategy	Bean output £ ha^{-1}	Oat output £ ha^{-1}	Total output £ ha^{-1}	Rank
RCRC	556	602	1158	5
VEVE	724	573	1297	3
CSRC	670	666	1336	2
UWRC	716	666	1382	**1**
OABE	619	518	1138	6
WHBE	568	533	1102	7
UWBP	700	567	1267	4

3.2 Selection of Variables for Inclusion in the LQI

To identify the important variables that impacted upon yield all the measurements recorded over the field season were correlated with combine yield using Genstat 6.1/7 for Windows (data not presented). Separate correlations were undertaken for both winter bean and winter oat crops. Once all the field measurements had been correlated with both sets of yield data the independent variables for use in regression analysis were selected on the basis of the following criteria; measurements with a strong positive or negative correlation ($>|0.3739|$, $P < 0.05$)[3] with the dependent variable, combine yield, were chosen as independent variables in initial regression analysis.

[3] |0.3739| refers to the magnitude of the number.

The selected variables were regressed in simple or multiple linear regression models taking into account soil texture as groups when appropriate[4]. The choice of variables that entered the regressions and the functional form (the relationship imposed by the choice of regression form, e.g. linear or log – linear) of the regression was made on the basis of significance of parameter estimates and the measure of goodness of fit, R^2.

Abbreviations used Equations (1) and (2)

Y	Output in t ha^{-1} of either beans or oats as appropriate	
BWt_1	Weed number line transect	6 August 2003
OAv_1	Available nitrogen	November 2003
OWq_1	Quadrat weed number	7 April 2004
S	Marginal soil intercept coefficient, estimated when $g = 1$	
g	0 for soil type 1 1 for soil type 2	
a, b	are parameters to be estimated	
***	$P < 0.001$	
**	$P < 0.01$	
*	$P < 0.05$	

3.2.1 Winter Bean Model Selection

As discussed above the choice of regression equation can be based not only on achieving a high R^2 value but also on the associated functional form. Thus in a simple linear regression the addition or subtraction of one unit of the explanatory variable (x) has the same marginal influence on the dependent variable (y) for all values of x. However, this assumed relationship between an independent variable (e.g. weed number) and the dependent variable y (yield) may be somewhat simplistic in certain circumstances. In comparison, a natural log transformation of an explanatory variable (e.g. weed number) implies that the marginal impact of x on y decreases as the value of x increases. Hence, in this example as weed numbers increase the marginal impact of each extra weed is decreased as total weed number is increased. Consequently, the relationship between yield and the natural log of weed numbers may be considered to be more representative of an actual field situation that would be the case given a linear relationship between weed number and yield.

[4] Soil texture in this experiment was defined as “soil” or “clay” groups.

Taking into account the issue of functional form, significance of individual parameters, R^2 value and agronomic knowledge, equation (1) (Table 7) was selected as the model to explain bean yield ($Y = a + Sg + b \ln BWt_1$). This estimated equation explains 68% of variation in yield and the estimated parameters are statistically significant. This model takes into account the two soil textures at the experimental site. In this case the intercept coefficients vary for each soil group. This regression model was chosen following a series of statistical tests to determine the significance of a change in the variables included in the model. Note that whilst equation (1) has only one explanatory factor (weed number), the inclusion of other explanatory factors did not significantly improve the estimated equation and hence these were excluded from the model.

Table 7. Winter bean model with associated parameters

Equation	$Y = a + Sg + b \ln BWt_1$ (1)
Adjusted R²	0.68
a	13.730 ***
S	0.648 ***
b	-2.347 ***

3.2.2 Winter Oat Model Selection

As with the selection of the winter bean model, the factors of functional form, significance of parameter estimates and R^2 value influenced the final choice of regression model. Equation (2) (Table 8) was chosen as the final model ($Y = a + Sg + b_1 OAv_1 + b_2 \ln OWq_1$). This was a multiple regression equation with soil groups and having two explanatory factors; the natural log transformed (weed number) and the level of available nitrogen. The fact that the functional form imposed by a natural log transformation better represented the relationship between weed number and yield was discussed in the previous section. As a result weed data also underwent a log transformation in the selected winter oat model. A linear relationship was chosen to represent the relationship between available N and yield due to the low N levels observed in this study. However, this relationship may only be appropriate where N levels are low and/or limiting. Finally, although the addition of soil groups was often not significant this grouping was retained for parity with the winter bean model.

Table 8. Winter oat model with associated parameters

Equation	$Y = a + Sg + b_1 OAv_1 + b_2 \ln OWq_1$ (2)
Adjusted R^2	0.60
a	4.079 ***
S	-0.113
b_1	0.0205 ***
b_2	-0.464

3.3 Land Quality Index (LQI)

The mean value of Total Value Product (TVP; equal to total output £ ha^{-1} in Table 6) for each conversion strategy was used to determine a measured land quality index (LQI_m). In order to calculate the index the strategy with the highest TVP was first identified. Dividing the output of each strategy in turn by this value and multiplying the resulting number by 100 then calculated the LQI_m. This gave a series of LQI_m values of between 0 and 100 with the strategy having the highest output being valued at 100. The calculation of the LQI_m for the two organic crops of beans and oats showed that UWRC (100), CSRC (96.73) and VEVE (93.89) were the strategies with the highest index values (Table 9). Within those top three strategies there was a difference of 6.11 between the strategy with the highest index value (UWRC) and the strategy in third place (VEVE). Four of the strategies had an index value of more than 90 whilst the remaining three strategies had an index of less than 84.

Table 9. LQI_m for two organic crops

Conversion strategy	Bean output £ ha^{-1}	Oat output £ ha^{-1}	TVP Bean + Oat output £ ha^{-1}	LQI_m
RCRC	556	602	1158	83.79
VEVE	724	573	1297	93.89
CSRC	670	666	1336	96.73
UWRC	716	666	1382	100.00
OABE	619	518	1138	82.41
WHBE	568	533	1102	79.71
UWBP	700	567	1267	91.69

The winter bean and winter oat models described earlier were then used to calculate a predicted TVP. These models were used to predict the effect of the observed input (e.g. weed number or soil mineral nitrogen) on the output (yield) of each crop. Once a value for predicted yield had been obtained this value was multiplied by the price per tonne for each crop to obtain a predicted TVP. The TVP for both organic beans and oats was then added together to produce a two-year TVP. The two-year TVP was used to calculate an index for predicted values (LQI_p) which was obtained using the method described above and is presented in Table 10. The top three strategies in terms of LQI_p were UWRC (100), CSRC (98.75) and UWBP (95.57). Five strategies had an LQI_p of more than 90 and the range between the fifth (RCRC) and first placed strategies (UWRC) was 7.31 (Table 10).

Table 10. LQI_p for two organic crops.

Conversion strategy	**Predicted Bean output £ ha^{-1}**	**Predicted Oat output £ ha^{-1}**	**Predicted TVP Bean + Oat ouput £ ha^{-1}**	**LQI_p**
RCRC	652	589	1242	92.69
VEVE	670	595	1264	94.39
CSRC	692	631	1323	98.75
UWRC	697	643	1340	100.00
OABE	571	559	1131	84.41
WHBE	569	524	1093	81.59
UWBP	699	582	1280	95.57

3.3.1 Comparison of Actual and Predicted LQI

A comparison of actual and predicted values (LQI_m and LQI_p) was undertaken following Gençay and Yang (1996). This calculated the absolute percentage error (APE) as, APE = $\left|\frac{O-P}{O}\right| * 100$ where O was observed output and P was predicted output. This method was chosen because the data used to calculate the TVP for the predicted output was generated by two models, one for the calculation of the bean TVP and another for the calculation of the oat TVP. A mean percentage error (MAPE) was then calculated for each of the seven conversion strategies.

A MAPE was calculated for all 28 observations[5] (5.19) and also using the means of the seven conversion strategies (2.33) (Table 11). This meant that there was a 5.19% error in the predicted TVP when all 28 observations were used which was reduced to a 2.33% error when the MAPE was calculated using the means from the seven conversion strategies. The MAPE provides a measure of goodness of fit of the overall combined model.

[5] Derived from four plots for seven conversion strategies.

Table 11. Mean Absolute Percentage Error, actual TVP compared to predicted TVP.

Conversion strategy	Actual TVP £ ha^{-1}	Predicted TVP £ ha^{-1}	MAPE %
MAPE 28 observations *			**5.19**
RCRC	1158	1242	7.27
VEVE	1297	1264	2.53
CSRC	1336	1323	0.98
UWRC	1382	1340	3.07
OABE	1138	1131	0.64
WHBE	1102	1093	0.77
UWBP	1267	1280	1.08
MAPE			**2.33**

* Individual data not presented

3.3.2 Predicted AVP and MVP

Further analysis was undertaken from the results of the predicted output for each crop to capture additional input-output economic measures in this production process. Specifically, an average value product (AVP), which determines the average value of one unit of input in terms of output (£ ha^{-1}), was calculated. However, AVP analysis assumes all variation in output is determined by the one input factor (e.g. soil mineral N). Hence this assumption is highly restrictive as more than one factor influences yield variation. Thus, in order to calculate the financial impact of an additional unit of a particular input for any increase in that input value (e.g. N or weed burden), a further measure, the marginal value product (MVP), was also calculated from the predicted output. The MVP calculates the monetary value (in terms of output gained or lost) of each additional unit of an input. Depending upon the functional form of the chosen regression equation the MVP may have different values at various points on the "curve". For example, if the relationship between weed number and crop yield is log - linear there will be a greater reduction in yield for each additional unit of weeds when weed numbers are lower than when weed numbers are at a higher level. In contrast, if the relationship has a linear functional form then each additional unit of weeds will result in an equal reduction in crop yield regardless of how many weeds are already present. Using the regression models selected for winter beans and winter oats the AVP and MVP were calculated under a range of weed burdens and nitrogen input levels as outlined below.

3.3.3 Winter Beans

Table 12 presents the AVP and MVP for beans. In this case the AVP measures the average value of beans produced corresponding to one unit of weeds. The AVP varied from £179.48 to £3.49 for sand soil and £166.52 to £2.63 for clay soil when weed input was 10 and 150 respectively. Hence, when the weed burden is low, the associated value of bean output for each unit of weeds is high (£179.48) whilst at high weed numbers, the overall bean output is lower and, correspondingly, the output associated with each unit of weed being present is substantially reduced. The MVP measures the monetary value of output gained or lost for each additional unit of an input. For both sand and clay soil types, the MVP ranged from -£32.54 to -£3.24; hence as weed numbers increased by one, output lost varied from £32.54 ha^{-1} to £3.24 ha^{-1} dependent upon the total weed numbers present at that point in the analysis. The MVP analysis highlights the influence of the choice of functional form in explaining the marginal contribution (be it positive or negative) of additional units of inputs / burdens in production.

Table 12. AVP and MVP under varying weed abundance scenarios for sand and clay soil textures.

Weed input	Weed input logN	Bean Price £	Sand TVP Predicted £	AVP £	MVP £	Clay TVP Predicted £	AVP £	MVP £
10	2.30	200	1795	179.48		1665	166.52	
20	3.00	200	1469	73.47	-32.54	1340	66.99	-32.54
30	3.40	200	1279	42.64	-19.03	1149	38.32	-19.03
40	3.69	200	1144	28.60	-13.50	1014	25.36	-13.50
50	3.91	200	1039	20.79	-10.47	910	18.19	-10.47
60	4.09	200	954	15.90	-8.56	824	13.74	-8.56
70	4.25	200	881	12.59	-7.24	752	10.74	-7.24
80	4.38	200	819	10.23	-6.27	689	8.61	-6.27
90	4.50	200	763	8.48	-5.53	634	7.04	-5.53
100	4.61	200	714	7.14	-4.95	584	5.84	-4.95
110	4.70	200	669	6.08	-4.47	540	4.91	-4.47
120	4.79	200	628	5.24	-4.08	499	4.16	-4.08
130	4.87	200	591	4.54	-3.76	461	3.55	-3.76
140	4.94	200	556	3.97	-3.48	426	3.05	-3.48
150	5.01	200	524	3.49	-3.24	394	2.63	-3.24

3.3.4 Winter Oats

Variation in weed input with average N input

For winter oats the AVP of weed number had a range of £72.27 (weed input 10) to £3.48 (weed input 150) for the sand soil. Clay soil had a slightly larger range from £74.08 to £3.60 under the same weed input scenarios. The MVP for both soil textures was much smaller than that observed for winter beans having a range from -£5.15 to -£0.51 (Table 13).

Table 13. AVP and MVP with average N input under varying weed abundance scenarios for sand and clay soil textures.

Weed input	Weed input logN	Oat Price £	Sand TVP Predicted £	AVP £	MVP £	Clay TVP Predicted £	AVP £	MVP £
10	2.30	160	723	72.27		741	74.08	
20	3.00	160	671	33.56	-5.15	689	34.47	-5.15
30	3.40	160	641	21.37	-3.01	659	21.97	-3.01
40	3.69	160	620	15.49	-2.14	638	15.95	-2.14
50	3.91	160	603	12.06	-1.66	621	12.43	-1.66
60	4.09	160	590	9.83	-1.35	608	10.13	-1.35
70	4.25	160	578	8.26	-1.14	596	8.52	-1.14
80	4.38	160	568	7.10	-0.99	586	7.33	-0.99
90	4.50	160	560	6.22	-0.87	578	6.42	-0.87
100	4.61	160	552	5.52	-0.78	570	5.70	-0.78
110	4.70	160	545	4.95	-0.71	563	5.12	-0.71
120	4.79	160	538	4.49	-0.65	556	4.64	-0.65
130	4.87	160	532	4.09	-0.59	550	4.23	-0.59
140	4.94	160	527	3.76	-0.55	545	3.89	-0.55
150	5.01	160	522	3.48	-0.51	540	3.60	-0.51

Variation in N input with average weed input

Turning to consider the impact of N input, for sand soil the AVP ranged from £35.33 when N input was 10 to £5.41 when N input was 150 (Table 14). As with winter beans the range was slightly larger for clay soils having an AVP of £36.49 when N input was 10 and £5.49 when it was 150. As the functional form used to explain oat yield specified a linear relationship between yield and N input, the MVP was equal for all input scenarios (£3.27); indicating the value of an additional unit of N input was worth £3.27 ha^{-1}.

Table 14. AVP and MVP with average weed numbers and varying N input for sand and clay soil textures.

N input	Oat Price £	Sand TVP Predicted £	AVP £	MVP £	Clay TVP Predicted £	AVP £	MVP £
10	160	353	35.33		365	36.49	
20	160	386	19.30	3.27	398	19.88	3.27
30	160	419	13.96	3.27	430	14.35	3.27
40	160	451	11.29	3.27	463	11.58	3.27
50	160	484	9.68	3.27	496	9.92	3.27
60	160	517	8.62	3.27	529	8.81	3.27
70	160	550	7.85	3.27	561	8.02	3.27
80	160	582	7.28	3.27	594	7.43	3.27
90	160	615	6.83	3.27	627	6.96	3.27
100	160	648	6.48	3.27	660	6.60	3.27
110	160	681	6.19	3.27	692	6.29	3.27
120	160	713	5.94	3.27	725	6.04	3.27
130	160	746	5.74	3.27	758	5.83	3.27
140	160	779	5.56	3.27	791	5.65	3.27
150	160	812	5.41	3.27	823	5.49	3.27

4 Conversion strategy recommendations

At the end of the conversion period and first organic crop Huxham (2003) recommended the RCRC and UWRC strategies to the risk-averse grower. The first choice, RCRC was chosen for its medium, but stable, return during the conversion period coupled with the high yield from the organic wheat crop. Due to the failure of the under-sown wheat crop to produce a commercial yield the UWRC strategy was very similar to the RCRC during the conversion period. However, Huxham (2003) highlighted the potential for increased yields if the under-sown crop was well managed. Based on this potential for increased gross margin and the output from the farm model, Huxham selected this strategy as second choice for a risk-averse grower.

Gross margin calculations at the end of the five-year period, i.e. the two year conversion period and three organic crops, showed that without subsidies strategies were ranked in the order CSRC, RCRC, UWRC, OABE, VEVE, UWBP and WHBE. Thus in agreement with Huxham (2003) the first strategy that would be recommended to a risk-averse grower would be RCRC (in preference to CSRC as detailed below). However, this strategy did have the lowest bean gross margin and was only ranked fifth when gross margins for just the second and third organic crops were considered. As a result, the strategy may not be suitable for those growers requiring a stable income throughout the rotation period. However, weed control and SMN levels from this strategy are amongst the best of the seven strategies (Rollett, 2006). The UWRC strategy also recommended by Huxham (2003) to the risk-averse grower was ranked third in terms of the annual average gross margin at the end of the five-year period. This strategy had the highest gross margin for the second and third organic crops coupled with good weed control and SMN levels. However, this strategy cannot be recommended to the risk-averse grower in the long-term. As the under-sown wheat crop from Huxham (2003) failed to produce a commercial yield, there is considerable uncertainty regarding the effects that a more commercially viable yield would have on factors such as SMN, weed number and soil structure.

For a risk-taking grower Huxham (2003) recommended the CSRC and OABE strategies. CSRC was chosen as it had the highest mean annual GM of all the seven conversion strategies. However, due to the specialised market and yield variability of clover seed Huxham (2003) suggested that this strategy would not be suitable for all growers. The OABE strategy was recommended by Huxham when labour was limited in autumn or under various price or yield change scenarios.

In agreement with Huxham (2003) the CSRC strategy would be the first strategy recommended to a risk-taking grower. The gross margin at the end of the five-year period was £459 ha^{-1} over £100 ha^{-1} more than any other strategy. It also had a relatively stable income distribution throughout the five-year period as well as good soil structure, SMN levels and weed control. Providing a market for the clover seed was obtained, this strategy would offer a good alternative to the RCRC strategy for the risk-taking grower. In contrast to Huxham (2003) the second strategy recommended to the risk-taking grower would be, as discussed above, UWRC. The OABE strategy would be unlikely to be recommended due to the higher weed burden and lower SMN levels than many of the other strategies.

In conclusion, only the RCRC strategy would be recommended to a risk-averse grower. However, both CSRC and UWRC could be suitable conversion strategies, in the appropriate conditions, for a risk-taking grower. UWRC was also a promising strategy but without further work on the longer-term impacts of a successful under-sown wheat crop it can only be recommended to the risk-taking grower.

Using average gross margin data from Nix (2002) the average annual gross margin (without subsidies) at this site with the rotation prior to conversion, of first winter wheat, second winter wheat, winter barley and oilseed rape/set-aside, would be £258 ha^{-1}. Hence all conversion strategies produced an average annual gross margin over the conventional average, albeit that in the case of the two lowest ranked strategies UWBP (£277 ha^{-1}) and WHBE (£274 ha^{-1}) the difference was less than £20 ha^{-1} (Table 4). However, in contrast the gross margin from CSRC was more than £200 ha^{-1} greater than that which would have been achieved under the previous conventional rotation. The recommended strategy, RCRC, had an average annual gross margin of £357 ha^{-1}, £99 ha^{-1} more than under the conventional rotation.

5 Conclusion

The economic legacy and impact of stockless organic conversion strategies on the second and third organic crop has been considered. Using gross margin analysis derived from input-output data from a five year experiment, the results indicate that fertility building conversion strategies produce the greatest gross margin measures over the entire five year period. Sensitivity analysis confirmed the stability of these results.

A land quality index approach detailed and explained the impact of independent factors on the productive capacity of the second and third organic crops and further economic analysis detailed the average and marginal returns to increasing weed burdens and nitrogen as appropriate to each of the oats and beans crops.

On the basis of this research, for a risk-averse grower considering conversion to stockless organic production, a two year red-clover ryegrass conversion offers the most appropriate conversion strategy due to the overall relatively high financial returns and the agronomic properties derived from this strategy.

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