DEPARTMENT for ENVIRONMENT, FOOD and RURAL AFFAIRS **CSG 15**

Research and Development

Final Project Report

(Not to be used for LINK projects)

Project title	Conversion to organic field vegetable production
DEFRA project code	**OF0191**
Contractor organisation and location	HDRA Ryton Organic Gardens Coventry CV83LG
Total DEFRA project costs	£ xxxxx
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Project end date	30/04/04

Executive summary (maximum 2 sides A4)

Introduction, aims and objectives

When this project began in 1996 the UK supply of organic vegetables, from 2400 hectares, was insufficient to meet the growing market and the majority of organic vegetables were imported. It was a policy objective to enable UK farmers to meet the demands of this growing market. A farmer converting to organic agriculture is faced with a range of specific agronomic and economic challenges different from those of conventional agriculture and of established organic systems and a lack of knowledge about these challenges was recognised as a major barrier for individual farmers considering conversion. The overall aim of this project was therefore to provide information on the agronomic and economic performance of farming systems which included field vegetables as part of their rotations during the conversion period and in the years immediately afterwards. The project was commissioned in 1996 as Project OF0126T, later continued as OF0191; this report describes the findings from both projects. The projects were led by HDRA with HRI (now Warwick HRI), EFRC (Elm Farm Research Centre), and the Institute of Rural Sciences (University of Wales, Aberystwyth) as subcontractors.

The main objectives were:

1. To convert 12 ha (Hunts Mill) of the farm at HRI Wellesbourne to an organic system, with a rotation including field vegetables and arable crops.
2. To assess agronomic and economic performance of the crops grown, soils, weeds, pest and diseases, during conversion and for the first target rotation at Hunts Mill.
3. To assess the overall agronomic and financial performance during the first full cycle of the rotations at Hunts Mill, comparing scenarios where the initial fertility-building phase was 29 months, 17 or 7 months.
4. To assess the agronomic and economic performance during conversion at 10 commercial reference farms, representing contrasting scenarios of organic vegetable production.
5. To interpret and evaluate the data and to produce information appropriate to aid farmers who are undergoing, or who are considering undergoing conversion to organic systems, and to aid future policy making on related farming issues.

The reference farms were selected to represent three different scenarios of conversion (from conventional arable, from conventional intensive vegetable and from conventional mixed farms with livestock). The farms represented a range of sizes and were located in all the principle vegetable growing areas of England. The assessment period covered the two-year conversion period itself plus at least the first three years of certified organic production. The basic experimental approach was to use all the farms as case studies for monitoring and documenting the performance of the systems undergoing conversion. Comparisons were made between Hunts Mill and the reference farms and also between the reference farms representing the same vegetable production scenario and between the three different scenarios.

Summarised Key findings

Production of organic vegetables was shown to be technically feasible at both small and large-scale production levels, with farmers able to produce vegetables to the high standards required of the supermarkets and other outlets supplied. Vegetable yields were very variable, being influenced by type and fertility of the soil, seasonal weather conditions, management decisions (e.g. variety choice and spacing), weed problems and pest and disease pressures. Marketable yields were, on average, 30% lower than those expected in conventional farming. This was attributed to generally lower levels of nutrients, losses from pests and diseases and weed competition. Many of the crops grown by the reference farmers after conversion were ones they had not produced conventionally so there was a need to learn about the husbandry of these. Being too ambitious with the range of crops grown too, soon led to costly failures. Marketable yields were, on average, 20% below 'typical' organic yields as shown in the Organic Farm Management Handbook (OFMH) for established organic farms. There could have been a number of reasons for this; during and following conversion the farmers were learning and adapting to the new organic techniques as well as to new crops. In addition the soils were adjusting to organic conditions, it is often thought that the microbial communities in the soil gradually become more active and effective as the organic system becomes established. It was also recognised that comparisons with these 'typical' values has to be made with caution as they are estimates for 'typical' farms in 'average' years, specifically they don't normally take account of crop failures. There was no discernable trend, upwards or downwards, in yields on individual farms, over the four years in which organic vegetable crops were grown. The gross margins of individual vegetable crops were very variable and closely linked to scenario type, marketable yields, prices of the produce, and the costs of casual labour. The Hunts Mill site performed better financially than the average of the reference farms (respectively 65% and 7% above conventional 'standards'). This was largely because of the higher prices achieved as a result of selling to the wholesale sector rather than to packers.

In-conversion crops were grown at Hunts Mill (spring barley) and on one of the reference farms (potatoes and cabbages). Whilst this approach gave some experience of organic crop management and helped with cash flow, the yields and financial returns of the in-conversion crops were generally low, especially from the vegetables for which there was no price premium. In-conversion cropping reduces the opportunity for fertility building during the conversion period but there was no evidence, in the first cycle of the rotation, of this or varying lengths of fertility building resulting in a reduction of subsequent vegetable yields.

Although there were some problems with nutrient availability, particularly of nitrogen, soil fertility was not a major issue when adequate fertility building crops were grown. The green manure crops would have performed better if they had been allowed to grow for longer in the spring and modifications to the cash cropping might have allowed this. Animal manures or green waste compost were commonly applied soil amendments, mainly used to replace phosphorus and potassium removed in harvested crops. Regular soil analysis provided little evidence for changes in soil chemistry during the first few years of organic management. Problems with poor soil structure were identified on several sites. Although these were often inherited from the previous conventional management there was specific damage resulting from carrying out mechanical operations (e.g. harvesting) in poor conditions. A number of farms introduced livestock to contribute towards soil fertility, however, in most cases the financial returns did not warrant the investment required.

Weed management was an important issue. Control measures presented less problems than were originally feared but did occupy a large proportion of the overall casual labour, the sourcing and managing of this labour was time consuming and difficult. Some farms experienced initial problems when they expanded their organic vegetable areas too quickly. The adoption of new technologies (e.g. the finger weeder) meant that much less hand labour was needed in later years. New weeding machinery accounted for a large proportion of overall investment but this represented good value for money. On some farms there were isolated problems with perennial weeds.

Damage to crops by vertebrate pests (eg rabbits and pigeons) was in some cases severe, but non–vertebrate pests and diseases did not generally result in major losses. At Hunts Mill pest and disease measures formed only a small part of the overall management effort since a minimum intervention strategy was adopted with the emphasis on using resistant varieties or cultural control methods; the most significant problems here were with brassica crops. The reference farms either adopted an intensive spray regime or took no control measures at all. The approach chosen depended on the size of the farm and the market channel used; large farms aiming for supermarket sales generally felt that they could not risk even low levels of damage. The overall direct costs of pest and disease control were small.

Most farms opted for a staged conversion over a 5 to 10 year period (and several of the larger farms only ever intended to convert 20 to 50% of their land). This approach meant that the cost of conversion, in terms of income foregone during the in-conversion period and new investments, could be spread over several years and supplying the market better tailored. On all farms total variable costs and total fixed costs largely remained unchanged during and following conversion in comparison with their pre conversion levels. Regular labour numbers also remained unchanged, although management time increased. However, casual labour costs increased, on average by a factor of six, particularly on the larger initially arable farms. All farms experienced a decline in net farm income (by between £150 and £1300/ha/annum) during the conversion period. This was in partly due to taking land out of production for fertility building but was also related to the performance of the conventional section of the farm during the transition period with conventional prices falling. The decline varied according to farm type and the rate of conversion, with the decline being higher for intensive horticultural holdings and with more rapid conversions. Models indicated that there is potential to make greater net farm income from organic vegetable systems, relative to conventional, although this is reliant on maintaining high price premiums (an average of 80% premiums are required to maintain comparable organic and conventional net margins at current prices) and consistent crop performance and controlled costs. Improved financial performance, relative to their pre-conversion position, has only been achieved on two of the reference farms, although on a number of the other farms the financial performance has been better than prevailing conventional comparisons. Declining prices, the poor economic performance of the livestock enterprises and the lack of other profitable break crops have contributed to poorer whole farm economic performance

More specific key agronomic and economic findings can be found in the main report.

Conclusions
The project has demonstrated that the process of conversion from conventional agriculture to organic vegetables production is often quite complex involving a significant number of innovations and restructuring of the farm systems, including changes in production, the introduction of new enterprises and marketing methods. These have resulted in a number of physical, financial and management changes both during the transition process and on the final organic farm businesses. The project has demonstrated that large-scale organic vegetable production is technically feasible, with soil fertility, weeds and pest and disease problems overcome without too much difficulty. The biggest challenges have been marketing, managing labour and making it financially viable at the farm level. Organic Farming Scheme payments have only made small contributions to the ‘cost of conversion’. Conversions, especially on the larger farms, would seem to be preferable over a 5 to 10 year period, allowing time to make the necessary learning and adjustments.

Further research
Monitoring at Hunts Mill has been extended until 2006 as part of a new project: *Organic field vegetable production – baseline monitoring of systems with different fertility building strategies* (OF 0332). Monitoring of some of the reference farms has continued as part of the project *The Sustainable Vegetable Systems Network* (OF 0340). This project monitors agronomy and economics and aims to assist in the development of established organic vegetable systems. Economic conditions change and the impact of the new CAP reforms beginning in 2005 would merit further research. The models developed within this project could form the basis for this work.

Scientific report (maximum 20 sides A4)

1. INTRODUCTION

In 1996 when the project began, the UK supply of organic vegetables, from 2400 ha, was insufficient to meet the growing market with a retail value of £35M; approximately 70% of organic vegetables were therefore imported (Soil Association 1997). At the time most of UK organic vegetables were produced on small farms mainly located in the south west of England and in Wales. There were very few organic conversions on the larger more specialised field vegetable farms located in the east of the country where most of the conventional vegetables are produced.

During the conversion period the farmer is faced with specific problems, different from those associated with conventional systems and with established organic systems. The conversion period usually involves improving soil fertility by establishing fertility-building crops (legumes) so that cash crops can be grown without synthetic fertilisers or large amounts of bought-in manures. This period, and the early years of organic production, can also involve a steep learning curve to gain experience with new crop production practices and marketing approaches as well as a time when farm income may be reduced and capital investment required. In the mid 1990s it was recognised that a lack of information about these problems represented a serious barrier for individual farmers to change from a conventional to an organic system. MAFF (later DEFRA) consequently funded a series of projects to study conversion in each of the major farming systems (upland beef and sheep, dairy, arable and field vegetable production).

In 1996 HDRA was commission to undertake a study 'Conversion to Organic Field Vegetable Production' (Project OF0126T, later continued as OF0191). The overall aim of the work was to provide information on the agronomic and economic performance of farming systems which included field vegetables as part of their rotations during the conversion period and in the years immediately afterwards. **This report describes the findings from both these projects.**

The main objectives of the project were:

1. To convert 12 ha (Hunts Mill) of the farm at HRI Wellesbourne to an organic system, with a rotation including field vegetables and arable crops.
2. To assess agronomic and economic performance of the crops grown during conversion and for the first target rotation at Hunts Mill. To achieve this individual fields and crops grown at the unit were quantitatively and qualitatively monitored by:

2.1 assessing yields of cash crops and fertility building crops
2.2 assessing the soil nutrient status, nutrients removed and replaced within the cropping programmes
2.3 assessing weeds and the weed seed bank
2.4 assessing pests and diseases problems
2.5 assessing economic performance of individual crops and of the unit as a whole, considering crop gross margins, fixed costs and costs of new investments

3. To assess the overall agronomic and financial performance during the first full cycle of the rotations at Hunts Mill, comparing scenarios where the initial fertility-building phase was 29 months, 17 or 7 months.
4. To assess the agronomic and economic performance during conversion at 10 commercial reference farms, representing contrasting scenarios of organic vegetable production. Similar but less detailed assessments were conducted on these farms.
5. To interpret and evaluate the data and to produce information appropriate to aid farmers who are undergoing, or who are considering undergoing conversion to organic systems, and to aid future policy making on related farming issues.

The project was a collaborative one led by HDRA with three subcontractors:
Horticultural Research International (now **Warwick HRI)** provided field services at the Hunts Mill and Kirton sites and also had a scientific input; expert advice was available to assist with deciding on the monitoring programmes and with statistical interpretation of the data.
Elm Farm Research Centre (EFRC) OAS made twice-yearly visits to each of the farms and provided agronomic advice.
The Institute of Rural Sciences (IRS-University of Wales, Aberystwyth) provided assistance with the collection and interpretation of financial data. They also provided conventional Farm Business Survey (FBS) cluster data for each of the reference farms for comparisons purposes and helped to construct the models to estimate the costs of conversion.

The project was guided by a steering committee which met twice a year and had representatives of all the appropriate stakeholders including DEFRA, organic and conventional vegetable producers, growers from the reference farms, Soil Association Producer Services, EFRC Organic Advisory Service, Horticulture Development Council and vegetable packers.

2. METHODS

2.1. Site selection

2.1.1. Hunts Mill

Hunts Mill is a 13ha field located at HRI Wellesbourne, which is situated in the Avon Valley in Warwickshire. Until conversion began the Hunts Mill field had been cropped in a predominantly arable system since it was purchased by HRI in 1977 (with a rotation of three years of cereals and one year of experimental field vegetables). The soil is a poorly structured sandy loam, with low organic matter levels and marginal nutrient reserves for horticultural production.

The monitored part of the site was divided into six areas of equal size (1-6). Each measured 100 m by 80 m (0.8 ha). Each area was further split into six strips (A-F) for monitoring purposes. A further division was made for weed seed sampling, each strip being divided into quarters. Wild flower strips were established alongside each area in 1999. Vegetables were grown on a standard bed system (1.8m wide).

Hunts Mill was converted in a two-stage process; areas 1-3 were registered (with SA Certification Ltd) in August 1995 and areas 4-6 in August 1996. The site was completely stockless with bought-in green waste compost being applied during the fertility building periods. The basic target rotation for the site was: fertility building crop => high N demanding vegetable => low N demanding vegetable => cereal (undersown with fertility building crop). Short-term winter green manures (rye or vetch) were fitted in whenever possible (e.g. after potatoes or onions) to prevent nitrate leaching and to improve soil fertility. Some adjustments were made to this target rotation to test the effect of growing in-conversion crops (barley), to balance labour requirements and to accommodate the market outlets available. Other changes had to be made to enable perennial weeds to be controlled.

Three conversion strategies were compared (Table 1). Two years under a cut and mulched ley is clearly an expensive option for a stockless farmer and so other possibilities were explored. These differed with regard to the initial fertility building regime and the subsequent sequence of cash and fertility building crops. In Strategies B and C in-conversion barley was grown as the first cash crop instead of potatoes/cabbages as this reflected the practice at the time when there was a strong market for in-conversion livestock feed.

Table 1. Conversion strategies used at Hunts Mill.

Strategy	Duration of 1st crop sequence	Area	Initial fertility building	First crop	Second crop	Third crop
A	5 years	1 and 4	30 month grass/clover ley	Potatoes/ cabbages	Carrots/ onions/leeks	Spring barley (u/s)
B	4 years	2 and 5	18 months grass/clover ley	In- conversion Spring barley (u/s)	Carrots/ onions/leeks	Spring barley (u/s)
C	3 years	6	6 months vetch	In- conversion Spring barley (u/s)	Carrots/ onions/leeks	Spring barley (u/s)

Owing to the different dates of conversion the cropping of areas 4, 5 and 6 was phased one year behind that of areas 1, 2 and 3. This has enabled there to be some degree of replication of the treatments. Area 3 was cropped with an arable-type rotation with no vegetables being grown apart from potatoes.

Growing techniques aimed to follow the best organic farming practice of the time (based on advice from EFRC OAS). Irrigation was only available to aid crop establishment rather than to boost yields. All crops from Hunts Mill were marketed commercially as *Dene River Organic Produce*. This commercial aspect of the conversion had to be self-funding and so realistic constraints were put on capital investment.

2.1.2. Reference farms

Initially only 3 reference farms were included in this project; in 1996 very few farmers were actually converting to organic field vegetable production and it was thus unrealistic to find a greater number of sites suitable for monitoring. One additional reference farm was included in 1997 and in 1998 the project was expanded to include a further six farms raising the total to ten. Details of the farms are listed in Table 2. They were selected to represent three scenarios of conversion (all of which were expected to be important for organic vegetable production), to represent differing geographical regions where vegetables are produced and to represent the use of differing market outlets:

Scenario I Conventional arable farms converting to organic systems and introducing vegetables in the rotation (farms 2, 3, 5 and 8).

Scenario II Conventional intensive vegetable farms converting to intensive organic vegetable production (farms 1, 9 and 10).

Scenario III Conventional mixed farms with livestock converting to mixed organic systems with vegetables (farms 4, 6 and 7).

Table 2. Summary of reference farm information.

	County	Total Farm Size (ha)	Area converted (ha)	Soil type	Type of farm	Date conversion began	Type of conversion	Organic crops grown
1	Lincs. (Kirton)	46	3	silty loam	intensive vegetables	Spring 1997	staged	brassicas/potatoes/carrots
2	Lincs.	1580	712	silty loam	arable/root crops	Spring 1997	staged	brassicas/potatoes/carrots
3	Cambs.	121	75	sandy loam/ silty loam/ peat	arable/root crops	Autumn 1997	staged	brassicas/ potatoes/carrots/leeks
4	Warks.	30	30	medium clay loam/ heavy loam	mixed	Autumn 1997	single-step	potatoes/ brassicas/alliums
5	N. Lincs	2120	700	sandy loam/peaty	arable/root crops	Spring 1999	staged	potatoes/ carrots/broccoli/beetroot
6	Cornwall	70	17	sandy loam	arable/ mixed livestock /early veg.	Spring 1999	staged	early potatoes/brassicas
7	Devon	72	72	medium clay loam	arable/ dairy/ vegetables	Spring 1997	staged	potatoes/brassicas/ strawberries
8	Notts.	1500	190	light sand	arable/ root crops	Spring 1999	staged	potatoes/carrots/ onions
9	Lancs.	1215	49	sandy loam/ peaty	intensive vegetables	Autumn 1998	staged	brassicas/salads/carrots
10	Beds.	20	4	light sand	intensive vegetables	Spring 1999	staged	potatoes/ brassicas/leeks/ celery/

2.2. Monitoring methods

2.2.1. Hunts Mill

A computerised field diary was kept of all operations, growing practices, observations and scientific monitoring.

Total crop yield was recorded for each strip. Marketable and unmarketable yields were recorded where possible, using the Organic Marketing Company (OMC) wholesale market specifications. When appropriate, sub samples of unmarketable produce were categorised according to the reasons for their failure. The biomass accumulation of fertility building crops were measured at incorporation and whenever they were mown (using quadrat samples). The off takes and returns of nutrients were measured from dried sub samples of all crops, crop residues and compost additions.

Soil (0-30cm depth) was sampled routinely each year in late February/early March. As well as using standard ADAS techniques it was analysed by Natural Resource Management Ltd according to EFRC methodology – an approach considered to be particularly appropriate for the organic farmer. Sampling for mineral nitrogen determination (0-60cm) was also carried out at strategic dates.

The weed flora was monitored (using quadrat sampling) at least twice in every crop. Weeds were identified and counted and the percentage cover of each species estimated. Percentage cover of crop and bare ground were also recorded. The soil weed seed bank was monitored to establish if any of the practices or rotations used during conversion affected its composition. Soil samples were taken at sowing and harvest. The numbers of viable and unviable seeds were determined using flotation and filtration extraction methods.

As well as the harvest assessments, pests and diseases levels were determined by crop walking regularly throughout the growing season. This was normally done at times when the crops were under peak pest or disease pressure. Pest and disease damage was recorded on scales from 1-9 using standard keys and methods. At the end of the season assessments were also made of severity of pest and disease damage in relation to marketable yield.

For economic assessments, it was decided to concentrate on the close monitoring of individual crop costs since it was difficult to allocate realistic overhead costs to the organic unit. To calculate gross and net margins the variable costs, labour and machinery costs of all cultivation operations were recorded. Yields and financial returns from the Hunts Mill site have been compared with figures from the *Organic Farm Management Handbook 1999* and *2004* (Lampkin & Measures, 1999; Lampkin, Measures & Padel, 2004, for the 'wholesale' marketing channel), which hereafter have been referred to as 'typical organic' values, and with 'typical conventional' data from the SAC Farm Management Handbook (Chadwick, 1999) and DEFRA 10 year averages (DEFRA, 2001). The 1999 editions were used whenever possible since they reflected the prevailing situation when the study began; the later reference books were used for crops not appearing in the earlier editions. The limitations of these comparisons with typical values were recognized and therefore made with caution (see 3.2.3).

2.2.2. Reference farms

The performance of the reference farms was monitored through a programme of visits by HDRA and OAS staff and through records kept by the farmers. Visits were made to each reference farm at least 6 times during the year, each visit providing a 'snapshot' view. Additional data and information was gathered from assessments and records kept by the farmers, particularly with regard to crop yields, and through interviews and discussion with the farmers. Qualitative as well as quantitative information was collected. Wherever possible crops were inspected at harvest to assess levels of pests and diseases on the harvested crop and losses due to out-grades.

The number of fields monitored varied depending on the size of the farm. Soil nutrient status, weeds, pests and diseases were monitored using similar methodology to Hunts Mill. Some samples were also taken of crops in store to assess any further disease development post-harvest.

For each farm data was collected from the farmers' records and accounts, producing:

- Whole farm accounts. A set of accounts prepared to FBS standards for the pre-conversion year, the two in-conversion years and the first two to three years of organic cropping. These have firstly been compared with published FBS data with the best match for the region and farm size and type. Secondly in order to obtain a better comparison they have been compared with cluster group of farms sourced from the FBS database (Jackson et al, 2004). Farm size, location, farm type, standard gross margin and proportion of horticultural output were used as variables to select the cluster group.
- Gross margins for all organic vegetable crops, which were then compared with 'typical organic' and 'typical conventional' values appropriate to the farms (same sources as described in 2.2.1)
- Fixed costs; where possible these were allocated to specific crops to calculate net margins. Costs of management time devoted to conversion planning, information gathering and managing organic crops were also identified.
- Capital investments of new machinery, equipment and buildings needed for organic conversion.
- Land use and cropping details from the reference farms, combined with current conventional and organic gross margins from Farm Management Handbooks have been used to construct models in order to further to estimate the costs and likely effect of conversion.

3. RESULTS AND DISCUSSION

3.1. Reasons for conversion to organic field vegetable production

The biggest driver for conversion on the reference farms was for commercial reasons. Three farms mentioned declining returns from the conventional sector as being an important factor (farms 5, 8 and 10). The increasing organic market was mentioned by seven farms as a major reason (farms 3, 5, 6, 7, 8, 9 and 10) and two of these farms (farms 6 and 9) had been asked to convert by their customers (packers). Commercial reasons were also mentioned on farm 2, but environmental and philosophical reasons were equally important here. The government conversion grants helped the process of conversion, but were only specifically mentioned by two farms (farms 5 and 10). Environmental reasons were also important (farms 3, 4, 5 and 7), with one farm citing 'to farm in an environmentally friendly way and to make better use of skilled labour and management skills' as a reason for conversion (farm 3). Farm 7 had already farmed under the Countryside Stewardship Scheme and the success of arable field margins in encouraging predators of aphids had led the farmer to question the need for inputs. Two farms mentioned philosophical reasons (farms 2 and 4) and one mentioned the environmental costs of producing cheap food (farm 2). Only one farm mentioned reasons of personal health and the dislike of using chemicals as being a factor (farm 10). On the farms where conversion was primarily commercially or market driven, only a part of the whole farm was converted (farms 5, 6, 8 and 9). For one farm (farm 1, HRI Kirton), the major reason was to provide an educational and research facility in order to assess the technical feasibility and financial viability of organic vegetable production.

Conversion plans were produced for all of the reference farms and all were said to be suitable for conversion by the Organic Advisory Service (OAS). The advantageous points favouring conversion and the challenges, as flagged up in the conversion plans are outlined in Table 3. These points are picked up in the sections to follow to ascertain their validity.

Table 3. Factors influencing suitability of the reference farms for conversion

	Positive factors	**Negative factors/challenges**
Infrastructure	Farms 1, 2, 5, 8 and 9	Farms 3, 4 and 8 (no livestock and plans to introduce it would be costly)
Soils	Farms 1, 2, 5, 6 and 9	Farms 8 and 10 (light soil so nutrients likely to be short)
Weed levels	Farms 2 and 8	Farms 3 (couch), 5 and 9 (annual weeds on black soils)
Closed system	Farms 6 and 7	Farm 3 (lack of manure availability)
Skills	Farms 1, 2, 5, 6, 8 and 10	Farm 4 (little farming experience)
Labour		Farm 4

3.2. Crop agronomic and economic performance

3.2.1. Fertility building crops

IN-CONVERSION FERTILITY BUILDING REGIMES. This period was one of the main differences between the three conversion strategies employed at Hunts Mill. Grass/white and red clover leys were employed for either 30 or 18 months (Conversion Strategy A and B respectively). They were managed by cutting and mulching three or four times per year. On average 9 t/ha dry matter containing 142 kg N/ha were finally incorporated – there was no consistent benefit associated with allowing the leys to grow for an additional year although the measured figures were undoubtedly an underestimate because of the difficulty of determining the true root biomass. Winter vetch was grown for 6 months in Strategy C. This crop grew well but had to be incorporated rather early in order to sow the following crop of in-conversion spring barley – considering the period for which it occupied the ground it was a very productive crop.

The advice given to the reference farms was to sow a fertility-building grass/clover ley during the conversion period and this is included in the standards as a requirement, where the land has previously been in exploitative cropping e.g. cereals. This was particularly important for the farms operating stockless systems (farms 1, 3 and 9). Farms 2, 5 and 10 had stockless rotations but with manure inputs and farms 4, 6, 7 and 8 had livestock. Those farms converting primarily arable or vegetable systems had less experience of growing grass and clover than the livestock farms. The time in grass/clover ranged from 7 to 30 months on the arable/vegetable farms with three years or more of grass on the livestock farms. There were some problems of establishment on farm 3 4 and 10. Farm 5 had more success from spring establishment than autumn drilling. The management of the crop was also problematic. Farm 5 had to devote considerable time and resources to the cutting and mulching of the grass/clover leys with up to 300 ha of leys at one time; this meant one tractor driver allocated full time to this operation during busy times (spring/early summer). Cutting and mulching ranged from 3 to 13 times during the fertility-building period, with more cuts needed on the more fertile sites. On four farms (farms 3, 4, 5 and 8) problems were experienced where the ley had been allowed to get too long and thatching occurred, with an excess of material preventing re-growth of the clover. Poor incorporation on two farms (3 and 8) led to grass sods hindering planting and drilling operations and re-growth of grass and clover was a major weed problem on farm 8. The need for fertility-building was often not fully realised at start of conversion, particularly on apparently fertile fen soils. Farm 9 had the shortest period of fertility-building of any of the farms (7 months) and ran into problems with lack of nitrogen at the end of the rotation. This farm also sold a silage cut off another grass/clover ley, which they later regretted. Farm 3 wished to reduce the fertility-building component of the rotation to over winter green manures only, due to the fertile nature of the soil. Other problems relating to the fertility-building were pests in following crops; wireworm in leeks (farm 5), slugs in celery (farm 3) and leatherjackets in lettuce and celery (farm 9).

FERTILITY BUILDING AFTER THE CONVERSION PERIOD. At Hunts Mill most vegetables were harvested too late in the year for winter cover crops to be established but they were sown whenever possible to minimise leaching and to provide a boost of nitrogen. Two species were utilised:

- Winter vetch (*Vicia sativa)* - a legume. This was sown after some of the onion crops. It was not very successful because of its late sowing and early incorporation.
- Grazing rye (*Secale cerale*) a non-legume. This was sown after some of the potato and onion crops. As with the vetch there were problems with late sowings and in some years it was not used when it was felt that the extra cultivations required to establish and incorporate it would be more harmful than the benefits it could bring.

The costs (seeds, cultivations, mowing) of over wintered green manures were found to have contributed to approximately 5% of the overall variable costs in the rotations at Hunts Mill.

Limited use was made of over-winter cover crops on the reference farms, despite the advocacy of them in advisory input. Although opportunities were often available, harvesting of crops inevitably took priority when staff or management time was limited. Growers were unfamiliar with them and when they were used they were often sown too late to be effective. However, as their conversions progressed their value became better recognised and growers began using them more and getting better at growing them (especially vetch on farms 1, 5 and 10).

At Hunts Mill all the cereal crops were used to establish leys by undersowing them with either pure white clover (over wintered until the following spring) or grass/white clover (grown on for one or two years to begin the next cycle of the rotation). These leys generally grew well. There was a dramatic effect on the amount of nitrogen addition achieved by delaying incorporation as long as possible in the spring (nearly twice as much biomass nitrogen was measured in May than in February). This meant that summer crops such as cabbages received greater fertility inputs than potatoes.

3.2.2. Cash crops

The agronomic performance of some of the key crops is described below.

POTATOES. At Hunts Mill the average marketable yield of the 13 potato crops grown was 30t/ha (range 18 to 41). Weed control was achieved mechanically with little hand weeding although patches of perennial grasses which had not been effectively managed during the rotation did become problematic and reduce yield. Potato blight was a constant threat in most years from July onwards but the use of resistant varieties and timely flailing of the tops prevented tuber infection. In the growing crop other pest and disease problems were limited. Skin finish, partially due to diseases such as scab, has not been good enough for supermarket retail. This was not unexpected because of the soil type and the fact that irrigation was not available.

Maincrop potatoes were grown on five of the reference farms. Three of the farms stopped growing potatoes towards the end of the project for marketing/economic reasons and because of the difficulty of achieving good skin finish. As the market for potatoes became well supplied these quality issues came to the fore. Yields ranged from 12 to 46 t/ha, with the lowest yield from a late planting (June) of a blight susceptible variety (Nicola). The highest yield was achieved on a small plot at HRI Kirton. Choice of varieties is important and those farms marketing through wholesale or direct outlets were able to be more flexible in choosing blight resistant varieties. Early potatoes were grown on two farms in the South West. Yields ranged from 5.5 t/ha to 11.5 t/ha. The low yield was due to a ridging checking the growth of one variety. Blight is a big threat in this area and slowness of marketing, due to supermarket programming and competition from imports, contributed to losses in one crop.

CABBAGE. At Hunts Mill the average marketable yield of the 12 cabbage crops grown was 1483 dozen/ha (range 0 to 3127). Cabbages have not been a very productive crop on this site; this is largely a reflection of the soil type. The best results were obtained when the weather permitted timeliness of cultivations and planting. Pigeon and crow damage (by both uprooting transplants and eating leaves) was a major problem. Weed control was straightforward and reasonably quick with an inter row hoe; the crop spacing allowing hand hoeing within the row. In later years the use of a finger weeder effectively reduced the need for hand weeding. Management of common insect pests such as aphids, caterpillars and cabbage root fly was a significant part of overall crop management in all seasons. The control measures taken against these pests (including soap and garlic sprays) increased production costs. Diseases, although present in all seasons were generally unproblematic, although ‘whiptail’ was a major problem, particularly in the Wirosa cabbages. This is a symptom of molybdenum deficiency but analysis of soil and plants showed no shortage; there may have been a transient problem with uptake, which was exacerbated by cabbage root fly attack to the root and stem.

On five of the reference farms a number of different types of cabbage were grown. Due to the differences in cabbage type, it has been difficult for yield comparisons to be made. The market was again critical and in 2001 large areas of cabbage were grown but not sold (farms 2 and 5) as a result of over-programming from the supermarkets/packers.

ONIONS. At Hunts Mill the average marketable yield of the 10 onion crops grown was 13t/ha (range 0 to 20). Onions proved quite a difficult crop to grow. Sets performed better on this site than the modular grown crop. Weed control involved hand removal in the rows and was therefore an expensive factor. In one year a black plastic much was used to suppress weeds but the method did not give good results. Normally three rows of onions were planted per bed - a four-row system was also tried but this reduced vigour and increased disease pressure. Diseases were the major crop protection issue, especially neck rot, a seed borne disease, which resulted in complete loss of the module raised crop in one season, and downy mildew, which was a problem in at least two seasons.

Only four crops of onions, in total, were grown on three reference farms. Farm 1 dropped onions after one year, due to severe white rot problems. Farm 2 grew two crops but dropped onions due to low returns and competition from imports. The marketable yield ranged from 7.9 to 20.4 t/ha and averaged 13.7 t/ha. The highest yield was achieved from a direct-drilled crop on farm 8.

CARROTS. At Hunts Mill the average marketable yield of the 12 carrot crops grown was 44t/ha (range 22 to 59). Carrots performed very well here and have been the most successful crop grown on the site. The open pollinated varieties were consistently vigorous with large roots and greatest yields. Fleece was used to manage carrot fly damage, but has not been as durable as envisaged, tearing in windy conditions and adding to labour costs. As it was used routinely it has not be possible to estimate its cost effectiveness. Leaf blight (*Alternaria*) was the main disease observed towards the end of most seasons but impact on yield was probably limited. Weed control has involved the use of stale seedbeds and pre-emergence flaming, which has been very effective in reducing the level of weed incidence in the crop. Irrigation during the period of crop establishment was crucial and yield suffered when this was not adequate.

Carrots were grown on five of the reference farms. Four farms grew maincrop carrots, drilling late to avoid carrot fly and average marketable yield was 40.6 t/ha (range 11 to 62 t/ha). Both the low figures and high figures from the range occurred on farm 1. The low figures were due to problems of marketing the crop and the high figures showed the potential for good yields on fertile soils. After a poor crop on farm 1 carrots were not grown again. Farm 5 grew bunching carrots, starting the early sowings under fleece, and at 450g per bunch averaged 27600 bunches/ha (range 21500 to 31800). Weed control was the biggest issue for carrot growers and those that persisted with carrots as a crop innovated in this area. On farm 5 they changed from 4 double rows on a bed to 8 rows and designed an inter-row hoe for that system. The thinking behind this was to remove the space between drills in the double row that then had to be hand-weeded; this helped to reduce costs.

LEEKS. At Hunts Mill the average marketable yield of the 12 leek crops grown was 11t/ha (range 7 to 13). Leek yields have been very varied. This could generally be explained by differences in weather conditions at planting; transplants that went in during a dry spell were checked and never achieved their full yield potential. Birds, continually uprooting transplants, were a major obstacle to achieving good crop establishment. There were also issues of soil fertility and problems with tip dieback and fungal infection. Three rows per bed grew better than four and nutrients may have limited the growth of the final leek crop in the most intensively cropped area. Mechanical weeding of the crops was easy to achieve. Thrips were present in all seasons but did not seem to affect marketability. Diseases were not generally a problem although leek rust was present in most seasons.

Leeks were grown on six of the reference farms, marketable yield averaging 10.3 t/ha (range 3 to 17 t/ha). Low yields on farm 2 were attributable to frost damage (inappropriate varietal choice) and too close spacing between the rows. The lowest yields were on farms aiming to market through the supermarkets (farms 2 and 5). On farm 5 yields also suffered in wet winter weather, through waterlogging.

PARSNIPS. At Hunts Mill the marketable yield of the single parsnip crop grown was 23t/ha. This was a successful crop with good yields and profitability being achieved with few problems. Parsnips were only grown on one reference farm (range 22 to 25 t/ha).

CALABRESE. Calabrese was an important crop on the reference farms. It was grown on seven of the farms with an average marketable yield (on six farms) of 5.5 t/ha (range 4 to 7.5 t/ha). Earlier crops were generally more difficult than later crops, suffering more from weeds due to slower establishment. On farm 9 (no yield data), cabbage root fly caused major yield loss in all years.

CAULIFLOWER. Summer cauliflowers were grown on six of the reference farms; marketable yield averaged (on five farms) 1200 doz/ha (range 0 to 1700/ha). Over-winter cauliflowers were grown on four farms averaging 878 doz/ha (range 530-1789 doz/ha). The low figure in the range was a crop in Lincolnshire (farm 5), badly hit by pigeon damage. Rabbits and geese also caused heavy losses on farm 7. The highest figure was in Cornwall (farm 6) on a farm experienced at growing the crop where similar yields to the conventional crop were achieved.

BRUSSELS SPROUTS. Sprouts were only grown on two farms and in one year only on each farm. Severe ring spot on farm 9 meant that only 50% of the crop was marketable.

BEETROOT. Beetroot was grown on four of the reference farms. The average marketable yield was 25 t/ha (range 7 to 40 t/ha). Beetroot proved to be a difficult crop to grow for two of the farms with nutritional problems (nitrogen and phosphorus on farm 5, potassium on farm 3) and weeds.

CELERY. Celery was grown on four of the reference farms, marketable yield averaging (on three farms) 2500 doz heads/ha (range 1700 to 3600 doz/heads/ha). On farm 9 (no yield data), considerable losses to celery leaf spot (*Septoria*) were suffered in the wet autumn of 2001. The farm estimated a 50% cut had been achieved, compared with 80% in the previous year. Problems of soil compaction contributed to lower yields on two farms (3 and 9)

LETTUCE. Three of the reference farms grew lettuce with mixed success. It is difficult to compare yields, as different types were grown. Farm 7 had no experience of vegetable growing and grew iceberg lettuces as an early crop, but suffered major losses to slugs and through check to crop growth after removing the fleece covering. Farm 9 had more experience and had a very successful first season with 74% cut of iceberg lettuce in 1999. Marketable yields were lower on this farm in subsequent seasons due to problems of selling the crop. Little gem lettuces were grown in two seasons on farm 1 (range 1500 to 2000 doz/ha), under fleece, which worked well in the first season but losses from tipburn reduced the yield in the second season.

COURGETTES. Courgettes were grown on three farms. Marketable yield (two farms) averaged 11 t/ha (range 8 to 15 t/ha). On all farms it was a new crop that they had not grown before. Getting into the market early and planting a succession to provide continuity improved yields on farm 5.

SWEETCORN. Sweetcorn was grown on five farms. The average marketable yield was 12000 cobs/ha (range 0 to 32500 cobs/ha), including two crop failures. This was also a new crop to growers. Only one grower was successful (farm 10) in producing good crops. One crop failure was in Lancashire, where cold weather meant the crop never established and another suffered from poor nitrogen supply.

CEREALS. At Hunts Mill spring barley, undersown with a ley, was used as a break crop from the vegetables. Although gross margins were low in comparison to vegetables the value of this crop as a means of establishing the following fertility building crops must also be considered. The average marketable yield of the 34 barley crops grown was 1.8t/ha (range 0.5 to 4.1). Spring barley performed well as an in-conversion crop but (following the initial fertility-building phase) but yields decreased when it was grown later in the rotation. A well-worked fine seedbed was essential for good establishment and early vigour. Soil structure and compaction problems hindered root development - there were clear after effects of the beds used for vegetable production where the wheelings had become compacted resulting in yellowed plants and reduced yields.

Winter wheat was grown on two of the reference farms. The average yield was 4.4 t/ha (range 3.5 to 5.17 t/ha). Only farm 2 grew spring barley; as at Hunts Mill this was undersown with a clover ley (two crops yielding 3.6 and 2.9 t/ha). Organic sugar beet was grown on two farms (two crops yielding 19 and 22 t/ha) and was dropped from farm 5 due to the high costs of production.

3.2.3 Agronomic and economic analysis of the organic vegetable crops

The yields and gross margins of the vegetable crops grown at Hunts Mill and on the reference farms are summarised in Appendix A. Comparisons with ‘typical’ values are also given here and in Table 4. There was a large amount of variability both within and between sites which were attributed differences in weather patterns, soil type and fertility, specific pest and disease issues, weed pressure, state of the market and management decisions affecting the timeliness of operations. There was no direct relationship between field size and crop performance, and there was no significant overall trend in crop yields over the course of the project, which might have been expected as farmers gained more experience with organic management.

Marketable yields were, on average, 30% lower than those ‘typical’ from conventional farming and 20% below ‘typical’ organic values. This was thought to be attributable to a range of factors; generally lower levels of nutrients, losses from pests and diseases and weed competition may have contributed. It is also notable that many of the organic vegetables grown by the reference farmers were crops that they had not produced conventionally, so there was a need to learn about their husbandry as well as organic management. Being too ambitious with the range of crops grown too soon also led to crop losses. It is also important to recognize that there are difficulties with comparing the averages (based on measured data) from this study with the published 'typical' values; the typical figures are usually estimates made for 'typical farms' for 'average years, in particular, the typical values do not normally include failed crops whereas the averages of the data collected in this project includes crops that failed because of agronomic problems or that were largely un-marketed because of poor market conditions at the time of harvest.

Table 4: Marketable yields and gross margins of all vegetable crops grown at Hunts Mill and on the reference farms expressed relative to 'typical' figures for organic and conventional production.

	Relative to 'typical organic'		Relative to 'typical conventional'	
	Yield	**Gross margin**	**Yield**	**Gross margin**
Hunts Mill	-18%	-28%	-29%	+65%
Reference farms	-18%	-40%	-30%	+7%

Hunts Mill and the reference farms had very similar marketable yields overall but gross margins were considerably better at Hunts Mill, largely because of the relatively high prices obtained there. When these prices were compared with 2004 organic packer prices (collected by HDRA for the *2004/05 Organic Farm Management Handbook*) it was found that 2004 packer prices were on average 30% less than those achieved. If data were modelled with 2004 packer prices and using average yields and variable costs from Hunts Mill, the resulting average gross margin would be 60% lower.

Although on the reference farms the yields were on average 30% lower (main range 25 to 50%) than conventional figures, prices were typically 50 to 100% higher resulting in gross margins, which were comparable to conventional levels (average of 7% higher). Gross margins from the organic vegetables averaged £3153/ha, but there was considerable variation, with a range of -£5,723 to £9885/ha. The highest gross margins were obtained on the smaller intensive farms, commonly on smaller land areas, using direct or wholesaling market outlets. (Table 5). More details are given in Appendix B.

Table 5: The effect of reference farm type on economic performance of vegetable crops (£/ha).

Farm scenarios	av. crop area (ha)	Total ha	Output	Variable Costs	Gross Margin	Fixed costs (allocated)	Net Margin
I: Arable	9.0	794	£6,126	£3,981	£2,145	£1,062	£1,083
II: Intensive vegetable	0.5	17	£10,672	£4,827	£5,845	£731	£5,114
III: Mixed	2.2	26	£4,623	£2,375	£2,248	£401	£1,847

When the distribution of all organic vegetable gross margins is examined from 1999 to 2002 (Appendix C), it can be seen that the majority of gross margins fell between £2,000-£4,000 each year. There was an increase in the proportion of gross margins within the £2000-£6000 categories from 64% in 1999/00 to 81% in 2002/03. At the same time, there was a reduction in negative gross margins to 5% in 2002/03. 2001/02 was a difficult marketing season, with much oversupply. The trends would appear to indicate that the reference farms organic vegetable financial performance has become more consistent, with less variation, since conversion began. This could be due to improved skills in growing and managing crops thus helping to reduce costs of production (e.g. reduced weeding costs), and also due to farmers diversifying into higher price direct and wholesale market outlets.

An analysis of variable costs of organic vegetables shows an average of £6230/ha for the five main vegetables at Hunts Mill (HM) and £4069/ha on the reference farms (RF). Casual labour (used for planting, moving fleece, weeding, harvesting, grading and packaging) accounted for the bulk of the variable costs: 56% (HM), 52% (RF), of this the largest element was for hand harvesting. Packing material and transport costs were 21% (HM) and 12% (RF), seed and transplants 18% (HM) and 22% (RF) of total variable costs. Crop protection costs, which include costs for fleecing, were relatively low (5%), indicating a minor direct influence on profitability. However, in some cases there were specific pest and disease problems resulting in very low marketable yields and negative gross margins; any expenses in crop protection can therefore also be seen as an insurance premium to ensure stable yields. A risk analysis shows that both hand weeding casual labour costs and crop protection costs had the highest variation and therefore introduced the highest risk into the system. Other costs like packing and transport, or seeds and transplants were more stable. In comparison with conventional growing costs, organic seed costs were found to be up to double and casual labour costs also higher. From analysis of data from this study and from OFMH it was found that overall costs per hectare of growing vegetables organic crops is often very similar to conventional crops (Appendix K). However, when the costs of organic growing are considered on a per unit basis (tonne or kg) the costs can be up to double that of conventional.

Allocated fixed costs and net margins were also calculated but cannot be compared to the 'typical' values since these are not available. At Hunts Mill, the average allocated fixed costs of vegetables crops were £591/ha (9% of variable costs), and £846/ha for the reference farms. Mechanical weeding costs accounted for 21% (HM) and 22% (RF) of the allocated fixed costs. At Hunts Mill, they increased by 43% during the four-year period. The hand weeding costs decreased in the same period (by 21%), therefore total weeding costs went down by 12%. The same trends were found at the reference farms. Carrots and leeks were the crops were hand-weeding costs were most successfully reduced during 1999-2002 on the reference farms.

3.2.4. Effect of cropping sequences on crop performance

The detailed measurements at the Hunts Mill site enabled comparisons to be made between crops grown within the three contrasting conversion strategies. A longer fertility-building period may be expected to build up more nitrogen in the soil that could then be utilised by the following cash crops. However, there was no clear relationship between the yields of any of the crops and either the length of the initial fertility building period or with the proportion of time spent in fertility building during the first full crop sequence. This may be because the issue is clouded by the variability of crop yields that were influenced by many factors other than the underlying fertility. Whilst long leys may not have a beneficial effect on nitrogen supply in the short term they may, however, aid in the build up of soil organic matter and in the control of pests, diseases and weeds.

On the reference farms the target or planned rotations were rarely followed strictly. Crop rotations were practised but it was most commonly a case of adapting cropping requirements in terms of market to the land available. This was particularly so for the first crops following conversion when a variety of crops might be needed for the market, meaning that less nutrient-demanding crops such as carrots might be grown as the first crop in the rotation following grass/clover, which would not normally be the case. The larger conversions (mainly arable) were able to be more flexible with rotation, particularly as new blocks of land came out of conversion. Two farms (5 and 9) put poorer fields back into grass/clover once better land had been converted. On farm 9 crops were observed to perform poorly at the end of the rotation (4th crop), after minimal (seven months) fertility building. There were problems on three farms with pests following the fertility-building period which impacted on yields; wireworm in leeks (farm 5), leatherjackets in lettuce and celery (farm 9), slugs in celery (farm 3).

3.3. Crop nutrition and soil fertility

3.3.1. Nutrient sources

Fixation from the atmosphere by growing leguminous crops was obviously the most important source of nitrogen at all the sites but there were also a number of 'fertiliser' inputs. At Hunts Mill green waste compost was spread on the fertility building leys, primarily as a source of P and K.

The situation varied on the reference farms. Some used no amendments during the period of study (farm 1 and farm 3) whilst others used a combination of brought-in animal manures and proprietary organic fertilisers (such as pelleted chicken manure) under derogation (farms 9 and 10, converting from conventional vegetable systems). On farm 9 the use of on-farm composted manure and green waste was very successful. Three farms introduced livestock into the farming system; farm 2 on a relatively small scale, largely relying on the grass/clover leys to provide fertility with manure both from their own herds and brought-in; farm 5 also converted a dairy farm to provide organic manure but could not make the dairy viable; farm 8 tried to establish and integrate an extensive outdoor organic pig enterprise, to assist in developing a livestock/arable/vegetable rotation (with the pigs utilising part of the ley phase) but also could not make it viable. Those farms converting mixed livestock systems used manure from their own livestock (farms 4, 6 and & 7). As with the other farms re-introducing livestock, the economic viability of the livestock component threatened the sustainability of the system. Reduced livestock numbers on farm 7, when the farm changed from organic dairying to raising calves, meant less manure was available for the vegetable part of the rotation.

3.3.2. Soil fertility – more individual farm details are given in Appendix D.

At Hunts Mill there was little change in pH during the monitoring period from the starting values of 6.0 to 6.6. There was no change in the total organic matter content of the soil (it remained at less than 2%). More detailed measurements of soil organic matter characteristics were made as part of a separate project to evaluate a range of soil quality indicators (OF0401). Mineral nitrogen measurements were made at strategic dates only; these illustrated a number of important points e.g. more mineral N was made available in the spring when incorporation of a ley was delayed as long as possible. Extractable phosphorus remained steady during the study (ADAS Index 4). Although this is considered an acceptable level, the results using the EFRC methodology would suggest that it is rather low. Extractable potassium showed a slight decline during the study using ADAS techniques (from Index 2+ to Index 2-). EFRC methodology suggested that this was rather low for horticultural production. Other nutrients remained stable; levels of magnesium were satisfactory, levels of calcium rather low, levels of iron were high, levels of manganese were generally normal, levels of zinc were low and copper levels normal. Problems were experienced with soil structure. Despite repeated attempts to alleviate the problems by increasing organic matter inputs (from leys and compost additions) and shallow ploughing in combination with various sub-soiling and top-soiling operations the soil was still very hard, capped badly and remained difficult to work. The most visible problem was compaction in the wheelings of the vegetable crops. They were clearly seen in subsequent cereal crops as pale green lines and are likely to have been a contributory cause of the poor cereal yields after vegetable cropping.

On the reference farms pH was effectively managed by routine applications of lime although our data shows a lot of annual fluctuation in pH levels. The target pH is the same in conventional and organic agriculture although some of the quicker acting lime amendments are not permitted under organic management. Organic matter levels varied greatly between farms reflecting the variations in soil type, e.g. farm 9 was on peaty soil with organic matter levels as high as 30%, farm 8 on a sandy soil had only approx. 1.5% organic matter. On the individual farms there has been little change in organic matter levels since conversion began. Available nitrogen was not measured directly but was assessed by examining crop performance; the two farms on the lightest soils (9 and 10) had the greatest problems. There was no overall pattern for P availability. The initial values were very different between sites and six of the ten farms had fields considered (according to standard EFRC interpretations) to be low in phosphorus. On some farms there was a slight decline in levels over the period of study, whilst in others there was an increase in P status. Initial levels of K availability were also variable between the various farms. Throughout the period of study, levels of available K tended to decline at all sites, though at this stage some of the rotations have not yet been completed. At the most recent sampling, seven of the ten farms had fields low in potassium (according to standard EFRC interpretations). Magnesium levels were generally stable – low levels were only measured at two of the farms. Six farms had high levels of at least one trace element (manganese, iron, copper or zinc). This was usually a reflection of basic rock type. Trace element availability can also indicate certain soil problems e.g. high manganese levels can be linked to compaction.

Problems related to poor soil structure were observed on several of the farms. Compaction was associated with harvesting of vegetables in wet conditions (as dictated by marketing considerations) and also occurred on some sites as a result of repeated mowing of fertility building leys. Prior to the conversion, soil structure and maintenance of soil fertility, were not specifically highlighted by the farmers as potential problems for their organic systems. However, as the conversions progressed it became apparent that these were important technical challenges on many of the farms and the need for information and advice on appropriate management strategies for improving soil structure, alleviating soil structure problems and for effective fertility building regimes (use of short term green manures) was identified.

3.3.3. Nutrient budgeting

At Hunts Mill nutrient budgets were drawn up for each strip for each completed crop sequence i.e. the point at which the fertility building phase began again. Measured values were used for crop off-takes in harvested material, compost additions and inputs by fertility building crops. Atmospheric deposition and leaching losses were estimated from literature values. More details are shown in Appendix E.

- **Nitrogen**. All the areas showed a small positive balance (+9 to +64 kg/ha/yr) but this was dependant on the compost applications. Much of this compost-nitrogen will not have been readily available (HDRA, 2000). Leaching losses generally exceeded removals in the crops. The timing of mineralisation is as important as the total amount supplied during the rotation.
- **Phosphorus**. The balances were clustered around zero (ranging from -8 to +4 kg/ha/yr). Areas where root crops (carrots and potatoes) had been grown had the most negative values.
- **Potassium**. The balances were generally negative (ranging from –62 to +19 kg/ha/yr). As with P, the most negative values were associated with cropping with both carrots and potatoes.

Net removals of P and K, at least in the short term, need not necessarily be seen as a problem if these nutrients can be made available from soil reserves. It is possible for these elements to be redistributed in the soil as a result of the action of plants and fungi (e.g. to be brought up from the subsoil by deep rooted plants). They can also be released from soil minerals through the action of weathering – this action may be enhanced by greater microbial activity, which is possibly a characteristic of well-established organic systems. It is, however, generally desirable that budgets should be balanced, especially on sandy soils. Management decisions should also be made in the light of soil analysis results. At this site phosphorus levels are adequate and have remained stable whilst potassium levels are low and have tended to fall; this suggests that if crops such as potatoes and carrots continue to be grown somewhat greater compost applications will be needed in order to avoid 'mining' the soil of its reserves.

3.4. Weed management

3.4.1. Weed flora at Hunts Mill.

This site had a relatively low weed pressure. Annual weeds were effectively controlled by a range of approaches: undersowing cereals with grass/clover, using stale seedbeds, by appropriate timing of mechanical operations such as steerage hoeing, brush weeding, thermal weeding and by hand weeding/rogueing. Weed management was not the primary consideration in rotation design; there was often a sequence of spring-sown crops, which would not be recommended, in the long term. Carrots followed potatoes in the rotation and this proved difficult with respect to volunteer plants emerging in the competition sensitive carrot crop. An increasing range of equipment was purchased for weed control over the course of the project (e.g. flame weeder, finger weeder); this improved weeding efficacy. The relative time and costs of weeding varied greatly between crops (e.g. potatoes have required little weeding, carrots and onions higher levels). As more experience was gained and new machinery employed mechanical weeding tended to replace hand weeding and overall weeding costs were reduced (see section 3.2.3).

Routine operations to control annual weeds were not enough to keep on top of perennial grasses and hand weeding not thorough enough to remove the entire plant. An increase in the presence of couch (*Elitrigia repens*) and black bent (*Agrostis tenuis*) was noted in 2000, especially in the potato crops. Weed levels actually prevented potato harvesting in some spots. In some of the vegetable crops smaller patches of perennial grasses were hand dug to prevent the spreading of the weed. In 2001 some strips had to be taken out of production and fallowed for the summer. The increase in perennial grasses highlights the need for vigilance before converting to eradicate small patches that can soon become bigger problems with the available organic control methods. There were also patches of horsetail (*Equisetum* spp.) in some areas, present before conversion, which have remained similar over the course of the rotation. These patches required extra casual labour (hand hoeing) to prevent the weed spreading.

In general the areas with the 30 month grass/clover ley initial fertility building period (Strategy A) had less weed problems than areas with the 18 month grass/clover ley (Strategy B). Strategy C, using an initial 6-month vetch crop followed by intensive cropping, also appeared to keep weeds in check. It was difficult to confirm this because factors such as timing and type of machinery were sometimes more important. The areas, which began their conversion later, were better managed as a result of increasing experience with the weed flora at the site and with the weeding equipment available. The impact of weather can also be very dominant when comparing different seasons.

3.4.2. The weed seed bank at Hunts Mill.

Because of the time consuming nature of sampling and analysis, counts were only made in areas 4, 5 and 6. There was an increase in viable weed seed numbers in all areas at the end of the first crop sequence. Seeds in Strategy A (a 5 year crop sequence) rose by 54%. In Strategy B (a 4 year crop sequence) they rose most by 495% while Strategy C (a 3 year crop sequence) there was a rise of 150%. This information supports that of the emerged weed flora to suggest that the 30-month ley is important in reducing the build up of the viable weed seed bank. However, it is the cash crops in these sequences rather than the fertility building crops, which may be responsible for this effect; the rotations containing greatest proportion of cereal cropping showed the highest increase in viable weed seed numbers.

In cropping strategies A and C a constant diversity of 15 weed species (± 2) was maintained. In B (beginning with an 18 month ley) there was an increase in diversity (to 21 species). These increases happened after both the cereal crops – there was a decrease after vegetable cropping. Strategy A became increasingly dominated by *Chenopodium album*, which comprised 70% of the seedbank by the end of the rotation. In contrast the other areas showed a much more equal composition of species. The increase in diversity and reduction in species dominance in Strategy B was due to the weedy nature of the cereal crops that allowed a range of weeds to flourish in the understorey; the main species increase occurred after a particularly weedy spring barley in 1998.

3.4.3 Weed management on the reference farms

Generally sufficient time and resources were devoted to weed control for effective weed management. New techniques needed to be learnt, such as flame weeding and the use of stale seedbeds, that growers were unfamiliar with. Investment was needed in weed control equipment on all farms. Approaches to weed management varied with the farming system and size of unit. The largest converting farms (mostly arable/vegetable systems) also had the capital available to invest in a range of machinery. The smaller farms, both intensive vegetable producers and mixed livestock/vegetable farms generally had less capital to invest in equipment. They have, however managed weeds effectively by adapting available equipment (farms 9 and 10) or by using contractors (farm 6). The general approach was to remove weeds wherever possible, preferably by mechanical means to avoid hand labour costs. Only one farmer (farm 7) took a more ‘laid-back’ approach and was able to tolerate weeds in the crop, helped by a long rotation with at least three years in grass.

Problems relating to weeds could be split into inherent farm resource issues (e.g. weed burdens, available staff, capital and machinery), and other issues often outside the direct control of the farmers (e.g. weather conditions). Large weed seed burdens for those on fertile black fen soils caused problems, particularly for drilled crops. Conversely lower weed pressures on some of the lighter soils meant that weed control was easier and their well-drained nature allowed larger windows of opportunity for mechanical weeding operations. The weather has had a major influence, e.g. in a wet spring stale seedbeds can not be created, but in a very dry spring there is no weed flush so they are ineffective; adapting to the weather has been critical, including irrigation, if necessary. High weed levels in crops have been recorded in wet seasons when weeding windows have been missed, weeds have grown fast and/or re-grown after mechanical weeding operations. Poor incorporation of grass/clover leys caused serious volunteer weed problems on two farms (farms 3 and 8), but other farms managed satisfactorily. Not all weeding machinery suits all systems and soil types, it has been a case of trial and error for most farms. One farm (farm 9) had problems with flame weeding (peaty soil) and did not get on with the finger weeder when trialled.

Many farms (farms 2, 5, 8 and 9) started off with a small area of cropping in their first year of organic status and managed weeds effectively, with a high level of management and attention to detail. The expansion phase, when farms (particularly the larger ones – farms 5, 8 and 9) brought large parcels of newly converted land into organic vegetable production has been more problematic for weed control. This may be due to an under-estimation of management time needed and conflict with other operations such as planting at times of peak labour demand. There were also technical issues of adapting equipment to larger areas (farm 8). Not controlling weeds at the optimum times has, occasionally, let weeds get away resulting in the ploughing in of crops or topping operations to minimise weed seed returns (farms 1, 8 and 9). Late conversion start dates for some farms (June) meant that in the first year of organic status, many crops were drilled or planted in a short space of time and weeding pressures all came at once (farms 3, 5 and 9). Weed problems have also led from other issues, e.g. poor crop establishment due to pests.

Perennial weeds are potentially an obstacle to the sustainability of an organic system and other studies have shown them to be problematic in organic arable conversions (Cormack, 1999). On two farms (farms 3 and 5) converting from arable systems couch (*Elytrigia repens*) has been a problem with bastard fallowing necessary to reduce weed levels and also a change in the rotation. This has had a cost. Creeping thistle (*Cirsium arvense*) has only been a problem on two farms but does not appear to be increasing. Docks (*Rumex spp*.) have only been a problem on one farm converting from a pasture-based system (farm 7) and also do not appear to be increasing.

Most crops have been hand weeded and sourcing labour for short periods has been very difficult. Management of the casual labour has also been difficult and time consuming particularly to get the right people and maintain quality of work. The trend on the larger farms has been to move away from local gang labour to using Eastern European labour through schemes such as Harvest Opportunities Permits Schemes (HOPS) and gangmasters.

The ability of farms to have a range of appropriate machinery available for an integrated approach to weed control has been crucial to success in controlling weeds. This has either been through investment, co-operation with other farmers (farm 8) or innovation and adaptation of existing equipment. Particular care was needed when past cropping led to a build-up of weeds such as weed beet and redshank on highly fertile soils. These challenges were flagged up in the conversion plans. Transplanted crops have proved easier to manage than drilled crops and some farms that have tried direct drilling of organic crops such as leeks, onions (farm 8) and sweetcorn (farm 10) have changed to transplanting for better establishment and weed control. Early crops were also more difficult as stale seedbeds are often not possible, crops establish less quickly and are less competitive. Experimentation and change of growing systems has been part of the learning curve following conversion. Consideration of weed control in all parts of the farming system is important, such as in the management of fertility-building crops, but also in the management structure, so that labour can be efficiently organised for weed control.

Weed control was a significant production cost ranging from 5 to 15% (£197 to £1213/ha) of both variable and allocatable fixed costs. The lowest costs were incurred for potatoes and the highest for carrots. Hand weeding costs ranged from £92 to £977/ha (18 to 195 hours/ha). On some of the farms (farm 5, 10) there was evidence of decreasing total weeding costs from 1999-2002 with increased mechanical weeding substituting hand labour. (See Appendix B for more details).

3.5. Pest and disease management

Pest and disease control was one of the biggest worries for farmers prior to conversion. Unlike the other agronomic factors of soil fertility and weeds, pests and diseases are much more influenced by season than rotational considerations. It is therefore harder to draw conclusions about the significance of one conversion approach rather than another.

Pest and disease management was a small part of the overall management effort at Hunts Mill and accounted for only about 5% of the variable costs. A minimum intervention strategy was adopted at this site at the onset of conversion and reliance placed on varietal resistance or cultural means of pest and disease control. Many of the crops were grown in strips of different species, which, because of its diversity, should also have helped to maintain pest and disease populations at low levels. Some habitat management was initiated, especially the sowing of flower strips adjacent to the cropped areas, but not really incorporated into the management plan.

At Hunts Mill pests were only a regular problem in cabbage and the use of reactive strategies (soaps, garlic and fleeces) increased towards the end of the project. A more proactive strategy could have been designed for use in this crop to boost marketable yields. Some cabbage crops were complete failures because of 'whiptail'; this was probably caused by molybdenum uptake problems linked to cabbage root fly damage at a critical stage of development. Fleecing of carrots against carrot root fly was a major cost but its effectiveness remains unproven at this site as compared to other management techniques such as late sowing.

At Hunts Mill potato blight was the major disease problem; it was effectively managed by flailing off the tops when disease pressure rose (the crop was planted early so that this did not affect yield too much). Neck rot in onions rendered the crop unmarketable in one year but this a seed-borne disease and so not a reflection on the agronomy of the site.

A wide diversity of pests and diseases has been observed on the reference farms, although few have caused significant economic loss. Some of the most significant losses were due to vertebrate pests such as rabbits, pigeons and geese. Of all pest and disease damage considered severe 21% was due to these large vertebrate pests. Losses due to disease have also been significant, accounting for 50% of severe rated damage. In some cases this has had a long term impact on the rotation, e.g. not being able to grow onions where white rot had occurred *(Sclerotium cepivorum*). Brassicas were the most problematic crops to grow having a wide range of pest and disease problems but also accounting for 50% of the severe rated problems. It is not surprising, therefore, that the greatest efforts taken to combat pest and diseases have been in brassicas, with a higher cost for these crops than others (10% of variable costs). The strategies on the farms have polarised, with farms either having intensive spraying regimes with high use of potassium soap, *Bacillus thurungiensis* (Bt), sulphur and copper (farms 2 and 5), or no control measures at all (farms 7 and 10). The farms with the most use of sprays tend to be the larger farms with bigger field sizes supplying into the packers and supermarkets. These are also the farms with the biggest risks (if crop is rejected there may be no alternative market). As specifications for organic produce have got tighter (Firth *et al* 2003), appearing to approach zero tolerance of pest or disease damage or presence, so have the number of sprays used increased on these farms. There also appears to be a correlation between plot size and severity of pest or disease attack, with more on the larger plots (Davies *et al*, 2002). There is considerable seasonal variation with wet summers such as 2000 bringing problems of slugs, potato late blight *(Phytopthora infestans*) and celery leaf blight *(Septoria apiicola*). Drier summers such as in 2002 have seen fewer problems. There have also been large differences between farms with one farm (farm 9) accounting for 40% of severe rated cases of pest or disease damage, mostly on brassicas. Pest and disease pressure was high due to high local populations of e.g. cabbage root fly (*Delia radicum*), past intensity of cropping (club root - *Plasmodiophora brassicae)* and wet climate (*Septoria* on celery). In contrast one farm (farm 10) had no recorded severe rated cases of pest and disease damage, influenced by lack of local vegetable producers, diversity of cropping in small plots and the use of crop covers on brassicas. That farm could also be more flexible in variety choice as supplying the wholesale market and could choose more resistant varieties that might not be favoured by supermarkets. The biggest losses due to potato blight on the reference farms were in varieties with little resistance such as Nicola and Lady Rosetta.

As at Hunts Mill, the costs for pest and disease control on the reference farms also accounted for less then 5% of variable costs. If a fleece was used (counted as crop protection cost) the costs could increase to 10% of variable costs. (see Appendix B for more details).

3.6. Whole farm economics, land and resource use

3.6.1. Management and labour

Management and labour issues have been critical on a number of the reference farms, but especially on the larger arable/vegetable farms. Management of organic crops took a lot more time than expected, farm 9 estimating 50% more time than for conventional crops. Farming systems have come under pressure during periods of expansion of organic cropping area, without corresponding increases in management staff (farms 3, 5 and 9). The increasing need for labour, particularly for hand weeding, but also hand harvesting, where more labour-intensive crops that cannot be machine harvested are grown, needs more management. Increase in number of crops grown after conversion and diversification of marketing, including embarking on new direct marketing operations such as box schemes all take increased management input. ‘Conversion of staff’, i.e. having backing of existing staff for conversion was an issue on one farm (farm 2), and providing continuity of management was a problem on two farms (farm 1 and 5). Two primarily livestock farms (farms 4 and 7) that had not previously grown vegetables found that the labour and management needs were high for organic vegetable growing and occasionally conflicted with other important tasks such as hay/silage making. A number of farms found sourcing and managing labour difficult (farms 1, 2, 3, 5, 7, 8 and 9). Three farms (farms 2, 5 and 8) took on extra managerial staff, partly for this purpose. The use of casual labour increased on all farms, up to a fourteen-fold increase on farm 5.

3.6.2. Marketing

Prior to conversion the reference farms used a variety of marketing outlets for their vegetables (6 farms using packers, 1 farm selling for processing, and 1 selling through wholesale channels) mainly related to their size, with the larger scale growers generally selling through the vegetable packers and processors. Those farms that had been previously supplying produce through the packers to the supermarkets continued to do so conventionally, using the same supply routes organically. As the organic market developed in the late 1990s and early 2000s (Appendix F) with a fast expanding UK producer base (Appendix G) and competition from abroad, marketing considerations soon became of greater concern to growers than technical growing issues. This became most obvious in 2001 when many growers had more problems in selling produce than in previous years. During this period, planning with the supermarkets became difficult, as packers and growers were uncertain of sale levels. This led to over-programming and loss of sale of crops in some cases. Farms have tended to diversify their marketing during the conversion process with an increased emphasis on wholesaling and direct marketing. Three of the farms started direct marketing for the first time. As UK supply increased during the course of the conversions farmers faced increasingly higher quality specification requirements, especially from the packers/supermarkets, and also the lowering of prices, all of which influenced the economics of production.

3.6.3. Comparison of conversion strategies

In order to assess the effect of organic vegetables on the whole farm economics it is necessary to also examine the economics of other crops within the rotation (Appendix J). Vegetables may form 25 to 80% of the crops in a rotation, depending on its intensity. The high value of the organic vegetables has to cover the cost of the fertility building periods, typically 25% of the rotation, and the lower valued crops. The economics of rotations on the reference farms has been hindered by the poorer performance of other crops in the rotation, especially so for the larger arable farms, which having converted, have often lacked other suitable break crops, which they had depended on when conventional, to make up a economically viable rotation. Neither sugar beet nor oil seed rape is a viable option for marketing reasons. Similarly, performance from the livestock enterprises on these farms has been weak. At Hunts Mill yields of barley were half of typical organic ones.

At Hunts Mill three conversion strategies were compared. Strategy A with the longest initial fertility building period (30 months) had the highest average annual net margin of 1744 £/ha/yr. This was different from Strategy C with the shortest initial fertility building period (6 months) with £1165/ha/yr. Conversion Strategy B (18 months initial fertility building) had a significantly lower net margin (£514/ha/yr). These differences were, however, not directly attributable to the length of the initial fertility building, it was the percentage of vegetable crops in the rotation and the choice of crops, which influenced it mainly. Seasonal effects were also present because the key vegetable cropping period was in different years (1998 for C, 1998 and 1999 for B and 1998, 1999 and 1999, 2000 for A). However, by adjusting for this effect, using average vegetable net margins, the differences between the strategies were still found (further details in Appendix J).

During the two-year conversion period itself, there were very low gross and net margins due to a lack of income from cash crop vegetables. Set-aside payments on the grass-clover leys (Hunts Mill was able to claim these) during conversion together with the sale of in-conversion barley helped to maintain a positive net margin in the range of 100-200 £/ha for grass clover leys and 300-400 £/ha for spring barley. However, these short-term cash flow benefits of the in-conversion cereals during the conversion years did not result in higher gross or net margins of the whole strategy. Indeed, the opposite was true; because less vegetable crops were grown there was less economic output, and the in-conversion barley led to greater weeding costs for subsequent crops.

Set-aside payments claimed in the 18-month and 30-month fertility building periods increased the net margin of the whole crop sequence by 20% for Strategy B and 8% for Strategy A, respectively. However, the 6-month rotation for which no set-aside payments were eligible still had a high net margin. If organic aid of £90/ha/yr (average of £450/ha over a 5-year period, for land eligible for Arable Areas Payments (AAP) is added the average net margin of all rotations at Hunts Mill (£1139/ha/yr) would be increased by 8%. However, if the land had not been AAP registered (much intensive horticultural land was not at the time) then the rate of the organic farming scheme payment would have been £350/ha over 5 years and this would have contributed an additional £70/ha/yr and added 6% to net margins. This land would also not qualify for set-aside payments.

It can be concluded that organic aid at this level does not have an important effect on organic horticulture. A successful vegetable crop output with good yields and high prices is key to the economic success of a conversion strategy. At the Hunts Mill site, yields were more variable than prices. Costs of vegetable production, especially related to the use of casual labour for weeding, harvesting and grading have been high. In terms of cash flow, these costs have all been borne before harvest. At Hunts Mill, the vegetable crops able to produce such good results were potatoes, carrots and parsnips. Leeks and cabbages were more difficult but also contributed to the economic success of a conversion strategy. Onions did not do well but the more successful crops compensated for their poor performance. (More details in Appendix J).

3.6.4. Land use changes

During the conversion process to organic vegetable production one of the biggest changes came from taking land out of cash cropping and putting it into grass clover leys for fertility building during the two-year conversion period, during which crops grown cannot be sold as organic. On the reference farms parcels of land were entered into conversion each year with the whole transition process being staged over 2-10 year period, at a rate of between 10-50% per annum. Following conversion the changes in land use have been determined by how much the farming system has changed. Where organic vegetables were replacing conventional vegetables in a similar rotation, then land use changes were less significant (farms: 2, 5, 6, 8, 9 and 10). However, the larger arable farms (2, 5 and 8) reduced their arable cropping on average from 40% of land area prior to conversion to 25% following conversion (Appendix J). All farms increased their area of fertility building leys, prior to conversion on the arable type farms this was typically 6% of total land area and rose to 25% following conversion. One farm (farm 9) continued their practice growing vegetables on other farms' land, although this was less successful in organic farming partly due to the greater distance required to find organic farms with suitable land and secondly because the lack of knowledge of the land led to weed problems.

3.6.5. Changes in crops, enterprises and other resources

A number of the farms (farms 2, 4, and 7) had not grown field scale vegetables before their conversions and there was therefore a need to develop new skills and acquire new equipment. Where vegetables had been grown before the farms increased the average number of vegetable crops grown from 4 to 10. This involved gaining new knowledge and skills in these crops, often by growing small "learning-areas". A number of the previously stockless farms introduced new enterprises of organic livestock (farm 2: suckler cows, farm 4: sheep and suckler cows, farm 5: dairy cows and farm 8 outdoor pigs) but in many cases (farms 5 and 8) the financial returns, due to low prices for milk and pork from these new enterprises, meant they were not profitable. They introduced further risk to the farming system and were later abandoned. One farm purchased a crisp making factory in order to process its organic potatoes, however, after a short period this was sold as they were unable to make it financially viable.

Resource changes happened because following conversion all farms used considerably less bought in fertilisers and crop protection chemicals. Regular labour numbers have not increased on the farms although the type of labour changed with a greater requirement for management both for checking growing crops and supervising larger amounts of casual labour. Casual labour numbers have increased by 2 to 14 fold, with the largest increases on the larger arable/vegetable type farms. This increase has partly come about because of the greater need for hand weeding but also because the farms have increasingly grown crops, which require hand harvesting such as brassicas. Many of the arable type farms had only grown vegetable crops, which could be machine harvested (e.g. potatoes, carrots and onions) when they were under conventional management. Although new specialist machinery, such as flame weeders, has been purchased on many farms, overall machinery costs have stayed much the same as they were under conventional management; this has been due to savings made through reductions in arable cropping.

3.6.6. New investments and time required in gaining information on organic systems

New investments made were mainly for new equipment to help with vegetable growing and the amount of this varied depending on whether the farm had grown vegetables before and on the scale of production. The main items purchased were specialised weeding equipment, such as flame weeders. Where storage and packing of vegetables was undertaken on farm this was largely done in existing buildings. Conversion involved considerable information gathering time on behalf of the farmer or farm manager, this was for reading and understanding organic regulations, new production methods, attending seminars, workshops etc. Details are given in Table 6.

Table 6. New investments and additional time spent in information gathering on the reference farms.

Farm Scenario	Investments £/farm	Investments £/ha	Time hrs/farm
Arable veg.	40,000-50,000	25-50	420-520
Livestock veg.	0-5,000	50-75	300-400
Intensive veg.	4,500-10,000	225-250	200

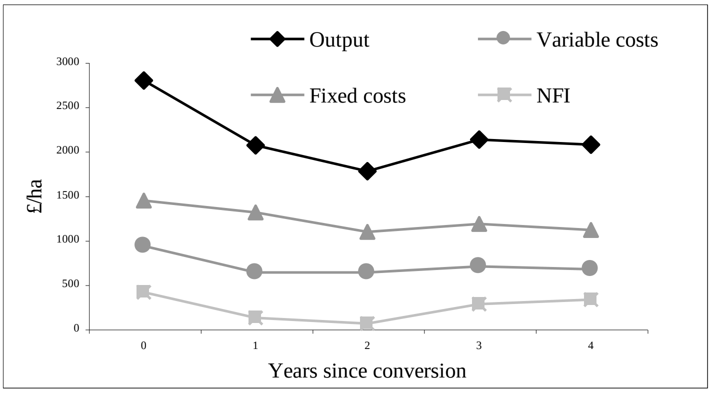
3.6.7 Changes in outputs, variable and allocated fixed costs

For confidentiality reasons all farms have been combined with the same starting year, averaged and compared with regional published Farm Business Survey (FBS) and cluster data obtained from the FBS database. Although all the farms were different in detail there were some general trends.

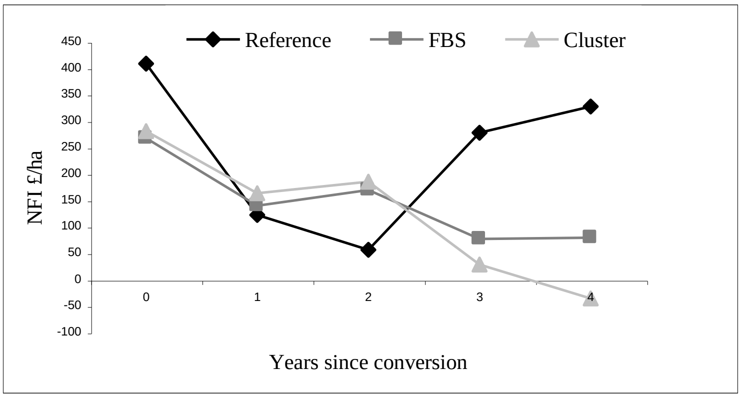
Before conversion all the reference farms were profitable with an average net farm income (NFI) of £409/ha (range £108 to £742/ha) (Figure 1a). The values were above both published FBS and cluster data (Figure 1b). In the year conversion began (Yr 1) output, costs and NFI per hectare fell on all the farms. All the farms, except the livestock farms, took a proportion of land out of crop production each year and put it in to a two-year grass/clover ley. There was no crop to sell from this land for the first two years in conversion phase, however, the farms with AAP registered land were able to claim set aside on this land. This was one of the major factors, which led to a decline in financial output during the first two years following conversion. Output was still below the pre-conversion year in the third year when organic production began and it never got to pre-conversion levels.

Figure 1. Reference farm financial performance and comparison with conventional data.

a) Average total output, variable & fixed costs and net farm income*



b) Comparison of NFI with FBS and cluster data



* Year 0; conventional, year 1&2; in-conversion, year 3 (av. 37%) and 4 (51%); organic

The rate of decline of output on most of the farms was related to the amount of land, which each farm put into conversion per year; this ranged from 6 to 38% and is referred to here as the rate of conversion. It was found that the faster the rate of conversion the more rapid the decline in output was. However, since considerable amounts of land were still in conventional cropping in the initial years it is estimated that approximately half of the output decline can be attributed to the fact that conventional prices also fell during this period (conventional cereals prices fell from £120/t to £80/t) and this effected the part of the farm which was still conventional. The rate of decline in output was also related to the intensity of production, or level of output prior to conversion. The intensive vegetable farms had the highest output prior to conversion and this fell by 50% in the two years following conversion. These farms also received a lower rate of organic aid (£350/ha) and were unable to claim set aside on fertility building leys, as they were not registered for arable area payments.

Farm costs also fell during the conversion period. Since a part of each farm was not in cash cropping naturally less variable costs were incurred and these fell by an average of 30% during the in conversion period. Fixed costs also fell by 20%; the most notable cost to fall was contracting especially on the larger farms, as less mechanically harvested crops were grown. Once organic production began variable and fixed costs were still slightly below pre conversion levels. During the conversion process overall labour costs stayed at the same as pre-conversion levels on most of the farms, but rose to 30% higher following conversion. Regular labour numbers and costs did not increase but casual labour numbers and costs rose significantly, this was especially so for the lager arable farms where the average wages bill for casual labour rose by a factor of 6 in comparison with pre conversion levels. The additional casual labour was mainly employed for hand weeding and to harvest the wider range of crops grown. Overall machinery costs fell during conversion and into the first year of organic vegetable production by 10%. Investigation of the different farms reveals some variations; where the farms had grown vegetables prior to conversion the total costs fell or stayed at a similar level, but on farms where vegetable production had been limited there was large increases in machinery costs (+30% on one farm). This was due to the need to make investments in new machinery.

Net farm income (NFI) on average fell during conversion in the first two years following conversion (Figure 1a), with two of the farms registering negative net farm income during these years. It is no doubt that the decline in conventional prices during this period contributed greatly to this fall. Following conversion and the growing of the first crops, net farm income rose, although it was still below pre conversion levels. A comparison with the conventional sample's FBS and cluster net farm income (Figure 1b) shows that NFI on the reference farms rise above conventional comparisons, this shows the importance that the sale of organic vegetables made to income on the converting farms. This represented an average of 16 % of total output in that year. It should be noted that this upturn in the reference farms performance, relative to the FBS and cluster data, occurred in 1999 (on 3 farms) and 2000 (on 2 farms) when organic vegetable prices were relatively high. In 2001 and 2002 organic vegetable prices fell by an average of 20 to 30% and this would therefore have made a difference to the economics of conversion if the conversion process had begun later.

It was noted that during the conversions conventional NFI also declined (FBS and cluster, Figure 1b) and that the converting group average ended up with higher NFI compared to conventional, although many of the farms had not completed their conversion by this date. This average masks considerable variation, it also makes it difficult to discover the likely implication of a farmer converting today. In the process of analysis it has also been difficult to separate the organic and conventional aspects of the business, therefore it was decided to make use models to construct likely situations with current prices, or order to further investigate the situation.

3.6.7 Estimates of costs of conversion from models

Models have been devised in conjunction with the Institute of Rural Science, UWA in order to calculate the costs of conversion to organic systems with vegetables using current ‘typical’ costs and prices. Two models have been constructed to represent firstly, the larger arable stockless systems (Appendix H) which have converted and secondly, the smaller more intensive horticultural systems (Appendix I). The models, which are based on data collected from the reference farms, start with the conventional rotation and then the conversion of this land in a phased transition over a five-year period. They use standard rotations with typical crop gross margin data as detailed in the notes of Appendix H and I. Land use and crop gross margins, sourced from both conventional and organic farm management handbooks (2004 editions), were then multiplied to obtain a “whole farm gross margin”. Since it was noted that total fixed costs have largely remained unchanged, these have been excluded in the calculations. Finally conversion specific costs such as certification, information gathering and new machinery, where they alter the total machinery stock of the farm, are deducted to obtain a farm net margin. A number of situations were run using the models, with varying approaches to farm conversion (all at once or staged), yield assumptions and with and without organic farming scheme payments. Comparisons were made with the actual results from the reference farms.

The models indicate that there could be a variety of outcomes during and following conversion. There was potential to make greater profit from organic vegetable systems, with a higher farm net margin following conversion. However, this was dependent on good consistent crop performance in terms of yield, price and control of costs. In fact, few of the reference farms reached this optimum position; all but two of them achieved post-conversion farm net margins, which were below their previous conventional returns, this being mainly due to low marketable yields. The modelling confirmed that good economic returns are highly dependent on premium prices for organic vegetables. On average, the current standard figures that were used gave a 100%premium. If prices were to fall from current levels by more than 20% then returns would fall below conventional ones. This indicates that price premiums of 80% over current conventional prices are required to maintain profitability at conventional levels, if no cost savings are made in organic production.

This work confirms that farms converting will experience a decline in net margins, even after receiving organic farming scheme payments, during the transition period ranging from £150-£300/ha/yr for larger arable farms growing vegetables up to £1300/ha for intensive horticultural units. This has obvious cash flow implications during this period. The models also suggest that a phased conversion is financially preferable to a short single-step conversion. Organic farming scheme payments only contribute an additional 6% (arable/horticultural) and 3.5% (intensive horticultural) to net farm margins during the transition period, again emphasising their marginal contribution.

4. Specific Key findings

Management of the conversion process

- The biggest driver for conversion on the reference farms was commercial reasons. With declining profits from conventional agriculture at the time, the potential of the organic market appeared attractive.
- Most of the farms followed a plan of gradual conversion over a 5-10 year period; the livestock farms were generally converted more rapidly. Demand from the market caused some farms to accelerate the rate of their conversions and where this happened it contributed to management problems and crop losses.
- Seven of the 11 farms studied had completed their conversions by the end of the monitoring period. The remainder, the larger initially arable farms, had not completed the process by 2003. Many of these farms had only intended to convert a proportion (20-50%) of their land to organic production.
- One of the biggest production and land use changes came from taking land out of cropping and putting it into grass clover leys for fertility building during the two year conversion period (in which crops can not be sold as organic). This led to major changes in farm output, costs and net farm income.
- Initial difficulties with establishment and management of grass/clover leys were experienced on many farms.
- Considerable management time (400 to 500 hrs/farm over first 3 years) was required to gather and learn about organic certification and production systems and to educate staff in these. Subsequent management of organic vegetables crops also took more time than conventional crops.
- On farms where land was registered for arable area payments the loss in income due to land being in fertility building was partly offset by the ability to claim set-aside payments on grass clover leys; the intensive vegetable farmers without arable land were not able to claim this. Organic Farming Scheme payments, which were increased to £450/ha over 5 years in 1999 (£90/ha/yr), also helped, although this only contributed between 3-6% of farm net margin.
- Many farmers were also able to take advantage of other environmental schemes (e.g. Countryside Stewardship) to help develop habitats favourable to organic production during the conversion period.

Crop agronomic and economic performance

- Where in-conversion crops were grown, financial returns were generally low, especially from the vegetables, due to low marketable yields and the availability of only a limited price premium for them.
- On many of the reference farms a diverse range of vegetables were initially grown on small areas in order to gain experience of the new production techniques and of marketing organic produce.
- On the reference farms, the growers were found to have managed their crops well and were found to have been able to adapt relatively easily to organic growing methods, with problems only arising where farms had less or no experience of vegetable growing or tried to grow too many crops for which they had no experience.
- A greater range of vegetable were grown organically than had been grown pre-conversion, with farmers on average increasing the number of vegetable types from four to ten. The most commonly grown vegetables were potatoes, cabbages, leeks, calabrese and cauliflowers.
- Vegetable yields at Hunts Mill and on the reference farms were very variable, being influenced by seasonal weather conditions, the type and fertility of the soil, market outlet used, management decisions, weed problems and pest and disease pressures.
- There was no significant overall trend, upwards or downwards, in average yields and gross margins over the four years in which organic vegetable crops were grown, although in the years 2000-2002 there was an increasing concentration of gross margins within the £2,000 to 6,000/ha range. This would appear to indicate more consistent performance as the farmers gained experience of growing the crops and controlling costs. It was notable that total weeding costs declined, as greater use was made of mechanical techniques replacing hand labour.
- The gross margins of individual vegetable crops varied by a factor of 15, ranging from £9,885 to -£5,723, with a mean of £3,153. The variation was closely linked to the marketable outlet used, yields, prices obtained for the produce and costs of casual labour. Average gross margins were only 7% higher than conventional ones.

- At Hunts Mill there were no clear effects on crop yields as a result of varying the length of the initial fertility building period in the first cycle of the rotation. However, more attention to fertility building may be needed in further cycles of the rotation as some crops were clearly lacking in nitrogen, although the demands were moderated by adjusting plant spacing.
- On average, marketable vegetable yields from the first four years of organic production (1999-2002) were 30% lower than 'typical' yields from conventional farming. This was probably due to generally lower levels of soil nutrients, lower plant densities, losses from pests and diseases and weed competition and less specialisation by the growers as more vegetable types were grown.
- Marketable yields were, on average, 20% below 'typical' organic yields as shown in the Organic Farm Management Handbook (OFMH) for established organic farms. There could have been a number of reasons for this; during and following conversion the farmers were learning and adapting to new techniques as well as to new crops, and the soils were adjusting to organic conditions. It was also recognised that such comparisons have to be made with caution as 'typical' values are estimates for 'typical' farms in 'average' years, specifically they don't normally take account of crop failures.
- As the quantity of UK grown and imported organic vegetables began to increase in 2001 their marketing became a greater challenge than technical growing issues. Many of the farms diversified their marketing outlets and often included direct sales.
- The market specifications rose and prices of vegetables sold to pre-packers fell (by 20 to 30%) between 1999 and 2002 and this had a negative impact on growers supplying these outlets.
- Planned rotations often had to be modified due to market demands, often to the detriment of agronomic needs.
- From analysis of data from this study and from OFMH it was found that the production costs per unit of organic vegetables grown were in some cases to be twice those of conventional vegetables. This was mainly due to higher seed and casual labour costs and lower yields.

Fertility management

- There were few changes in the extractable nutrient or organic matter contents of the soils on any of the farms during the period of monitoring.
- Some farms used no soil amendments during the period of study whilst others used manures or proprietary fertilisers (e.g. pelleted chicken manure) or green waste compost. At Hunts Mill nutrient budgeting showed that additions of green waste compost were insufficient to replace all the P and K taken off when both carrots and potatoes were included in a crop sequence.
- Poor soil structure, and difficulties in overcoming and avoiding this, was identified as a technical challenge at several sites.
- Where livestock were kept to make use of grass clover leys and provide soil fertility, they were generally financially unprofitable; on two farms they were abandoned.
- Hunts Mill was successfully converted to organic field vegetable production despite the fact that the soil was in poor condition before conversion and of a type not ideally suited to vegetable production, especially of brassicas.
- Over-wintered green manures were planned in many of the crop rotations but were less often sown due to unsuitable weather conditions and conflicts with crop harvesting. In many cases the green manure crops would have performed better if they had been sown earlier or allowed to grow for longer in the spring; modifications to the cash cropping might have allowed this. The importance of including winter cover crops and other green manures was recognised by many of the farmers as their conversions progressed.
- There was a greater availability of soil mineral N for the following cash crops when fertility building crops were allowed to grow for as long as possible in spring.

Weed management

- Prior to conversion, weeds were perceived by most of the growers as being their biggest technical challenge for their conversion. Weed management did turn out to be an important issue for all farms, although in most cases weeds were generally managed effectively, but often at a high cost. Problems with perennial weeds were noted for specific fields on some farms.

- Sourcing and managing hand labour for weeding was time consuming and difficult. The introduction of new techniques and equipment on many of the farms reduced the need for so much labour and resulted in a reduction of weeding costs during the period of the project.

Pest and disease management

- Pest and disease control was also one of the biggest worries for farmers prior to conversion. Although a wide range of pests and diseases were observed on the farms, few caused significant economic loss. The most significant non-vertebrate pest problems were in brassica crops. Damage by vertebrate pests was sometimes severe. Potato blight was the most important disease.
- To manage pest and diseases farms either adopted an intensive spray regime or took no direct control measures at all, relying on varietal or cultural controls. The approach depended on the size of the farm and the market channel used.
- Pest and disease costs were generally less than 5% of total variable costs.

Whole farm economics

- On all farms total variable costs and total fixed costs largely remained unchanged during and following conversion in comparison with their pre conversion levels. Regular labour numbers also remained unchanged, although management time increased. However, casual labour costs increased, on average by a factor of six, particularly on the larger initially arable farms.
- All farms experienced a decline in net farm income (by between £150 and £1300/ha/annum) during the conversion period. This was in partly due to taking land out of production for fertility building but was also related to the performance of the conventional section of the farm during the transition period with conventional prices falling. The decline varied according to farm type and the rate of conversion, with the decline being higher for intensive horticultural holdings and with more rapid conversions.
- Models indicated that there is potential to make greater net farm income from organic vegetable systems, relative to conventional, although this is reliant on maintaining high price premiums (an average of 80% premiums are required to maintain comparable organic and conventional net margins at current prices) and consistent crop performance and controlled costs.
- Improved financial performance, relative to their pre-conversion position, has only been achieved on two of the reference farms, although on a number of the other farms the financial performance has been better than prevailing conventional comparisons. Declining prices, the poor economic performance of the livestock enterprises and the lack of other profitable break crops have contributed to poorer whole farm economic performance.

5. Conclusions

This project has confirmed that the process of conversion from conventional agriculture to organic vegetables production is quite complex involving a significant number of innovations and restructuring of the farm system, including changes in production, the introduction of new enterprises and marketing methods. These have resulted in a number of physical, financial and management changes both during the transition process and on the final organic farm businesses. The project has demonstrated that both small and large-scale organic vegetable production is technically feasible, with soil fertility, weeds and pest and disease problems being overcome without too much difficulty. Growers with previous conventional vegetable growing experience being able to adapt more easily. As expected financial performance was extremely variable indicating the risks associated with organic vegetable growing. Some of the biggest challenges have been marketing, managing labour and making it financially viable at the farm level. Organic Farming Scheme payments have only made small contributions to the ‘cost of conversion’, especially on the smaller intensive units where the costs are higher. Conversions, especially on the larger farms, would seem to be preferable over a 5 to 10 year period, allowing time to make the necessary learning and adjustments. Despite the perceived constraints to conversion, identified prior to the project, the area of organic vegetable production doubled during the period of the project with the total area of organic vegetables in the UK rising to 5,259 hectares in 2002. A number of factors have contributed to this including rising consumer demand, the influence of the multiple retailers, poor financial returns in the conventional market, and the policy interventions, which enabled the greater availability of information, advice and subsidies to meet the costs of conversion. In this respect the policy interventions would appear to have given a necessary boost. This project, through its provision of data and information, became increasing important as growers considered conversion, and there has been much interest and demand for the results and information coming out of it.

6. Future research

Although the project initially focussed on problems with the conversion period itself work later on was concerned with the establishment of effective organic field vegetable systems, particularly with respect to rotation design and the need to have a satisfactory balance between fertility building and cash cropping. This type of work is necessarily long term since it may take several cycles of a rotation before effects on soil fertility (and consequently on crop yields and economic performance) are fully realised. Monitoring at Hunts Mill has been extended until 2006 as part of a new project: *Organic field vegetable production – baseline monitoring of systems with different fertility building strategies* (OF 0332). Within this the three basic rotations will be maintained and the same agronomic and economic parameters will continue to be measured and will be collated together with the data gathered so far. Another aim of the project is to make the resources of the site available for additional, separately funded, work. The value of this is that experiments can be conducted within a context of excellent background information. Monitoring of some of the reference farms has continued as part of the project *The Sustainable Vegetable Systems Network* (OF 0340). This project monitors agronomy and economics and aims to assist in the development of established organic vegetable systems. The difficulty of devising appropriate management strategies for alleviating and avoiding soil structure problems and for effective use of fertility building crops has been identified as a specific technical challenge that need to be resolved. The need for detailed market information was also identified by the growers and this led to the commissioning of an annual study of the organic vegetable market (OF 0307) by DEFRA from 2001. Economic conditions change and the impact of the new CAP reforms beginning in 2005 would merit further research. The models developed within this project could form the basis for this work.

7. Dissemination

The results from the project have been, and continue to be, disseminated in a number of ways. Ten open days have been held at Hunts Mill and at six of the reference farms. In addition, four organic open days have been held at HRI Kirton at which the project has had significant input. These have all been well attended by farmers, growers and others from the industry and well reported in the popular farming press. Project staff have also spoken at a number of external events organised by, amongst others, the Soil Association, Elm Farm Research Centre and HDC. Meetings have been held with advisors from the OAS, ADAS and Abacus Organic Associates to disseminate the results and discuss findings. The project team have used the results to contribute to regular updating of the *Organic Farm Management Handbook* (edited by Lampkin and Measures). Project leaflets have been made and distributed through advisors and at shows and conferences. Papers have been presented to a number of conferences including the BCPC conferences in 1999 and 2002, UK Organic Research 2002 Conference and BGS/AAB/COR conference in 2004. Annual reports have been available and four page leaflets outlining the case studies of conversion for Hunts Mill and the reference farms have been written and are in the process of printing and being made available to the public. More details of these activities are listed in Appendix L. A website www.organicveg.org.uk, linked to the www.HDRA.org.uk/research website has been constructed which holds case study information and project research papers and reports.

8. References

These are listed in Appendix M.