Studies in Land Use Change and Socio-Economic Consequences

Research on the Consequences of Converting to Organic Production: A Review of International Literature and Outline of a Research Design for New Zealand

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Preface

Research on organic farming is of growing importance in New Zealand. While there is an increase of such research (see for example AERU Research Report No. 251) and increasing interest in such research, it is particularly important to do it thoroughly and give attention to how best to do it. This report has such a methodological focus in mind. Readers will find both a useful review of a diverse literature and the development of a research design that can be used to assess the effects of farm conversion to organic production under New Zealand conditions.

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Summary

The objectives of this research were to review the literature that describes the consequences of farms converting to organic production and to use these studies to develop an optimum design for an organic farm conversion study in New Zealand.

Research to date has been either longitudinal research on organic farms only or static/comparative with direct comparison between organic and conventional farms.

The Before-After-Control-Intervention (BACI) design advocated here builds on both types of research by reporting changes over time as some farms undergo conversion while others maintain conventional production. Research using this design is needed in New Zealand because we cannot assume that results from the international literature necessarily apply in New Zealand. The absence of significant New Zealand research needs to be redressed with careful and thorough study of farm conversion focusing on the full range of relevant variables including: environmental, economic, social, extension and health factors.

Chapter 1
Introduction

1.1 Background and Research Objectives

In many parts of the world, including New Zealand, some farmers are moving from conventional production to lower input systems such as organic, low-input or integrated production. In 2001, organic food exports from New Zealand were valued at $70 million while domestic market sales were estimated at $35-45 million (OPENZ, Annual Report, 2001). The three organic certifying agencies in New Zealand report around 900 organic licencees either fully certified or in transition[1]. Cook et al. (2000) and Fairweather et al. (2001) provide evidence that many more farmers are considering conversion to organic production. Consequently, while New Zealand has been a late entrant to organic production relative to Europe, the organic sector is becoming an important aspect of primary production.

Within the broad discussion of the significance and relevance of organic production for New Zealand, there is a belief among growers, industry groups and policy makers that organic production has different consequences for the farm, the farmer and environment (both on the farm and more generally). What exactly these consequences are is more difficult to judge with certainty. What is certain, however, is that in the absence of definitive research in New Zealand, there are different and contested views about the consequences of conversion. Internationally, there have been many studies of farm conversion and comparative studies of the attributes and performance of organic versus conventional farms and this research does contribute to informed debate about the consequences of conversion to organic production. Such analysis, however, has almost never been undertaken in New Zealand and there is no significant body of data outlining the consequences of conversion to organic production in New Zealand conditions[2].

This report provides a literature review of some of the many organic farm conversion studies conducted overseas, and uses these studies to provide a template for the optimum design of an organic farm conversion study in New Zealand. While the substantive findings of the studies reported here may be of general interest, the principle reason for conducting this review is to evaluate the style and methods of studying farm conversion and performance of organic versus conventional production.

1.2 Rationale

The research question is important to consider because in New Zealand there is considerable interest in organic production among farmers, industry groups and policymakers. Three recent bodies of work have reviewed the current status of organic production research internationally and in New Zealand. First, a recent Ministry for the Environment funded project carried out by the Biodynamic Farming and Gardening Association (BDFGA 2001) carried out a literature review of organic land management research focusing on soil science, orchard management and pasture management. Second, the New Zealand Institute of Crop and Food Research Ltd.

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[1] Bio-Gro NZ have approximately 700 licencees (Bio-Gro NZ pers. comm., 2001), Certenz has 170 licencees (Certenz pers. comm., 2001), and Demeter have 40-50.

[2] The pioneering study by Reganold et al. (1993) has never been rigorously followed up. Two small bodies of industry data were presented in Saunders et al. (1997) relating to sweet corn and kiwifruit production. Since then no publicly available studies have been carried out.

conducted a literature review and constructed a website of literature relating to organic crop management[3]. Finally, the Organic Products Exporters of New Zealand also constructed a web-based library of information on organic production, markets and education-providers. Reading all three of these bodies of research provides a clear picture of the large amount of production-related research being conducted overseas. There are, however, significant gaps in the research literature that are of immediate importance to New Zealand. First, there is a paucity of socio-economic analysis being undertaken outside the EU and particularly in New Zealand (see Campbell and Ritchie in BDFGA, 2001). Second, there is no significant study of the process of organic conversion in New Zealand. Reganold et al. (1993) provided an early preliminary study, and Macgregor (2001) began a study of dairy farm conversion but had to terminate the trial after one year in the absence of continued funding. The early research has not been followed up with any significant studies despite the best efforts of Macgregor.

This review poses the question as to whether international research on organics is relevant to New Zealand. Compelling results from the international literature may not be applicable in New Zealand. It seems likely that biological processes should be universal in their applicability. However, all biological processes are embedded in complex and possibly locality-specific interactions. Further, research on specific pest species may not be applicable in New Zealand especially where the pests do not occur in New Zealand (e.g., the European Corn Borer). Economic results are less likely to be applicable since the agricultural systems in Europe are subsidised, and New Zealand exporters face a range of market entry issues that are not relevant to the internal markets of North America or the EU. Clearly, the case can be made that there is a need for New Zealand research before the consequences of conversion to organic farming can be accurately understood in our local conditions. This review will provide a rigorous basis for the development of an effective design for research in New Zealand that will accurately document the consequences of conversion to organic farming.

1.3 Scope and Limitations

The general research question addressed by the research reported here is: what are the consequences of conversion to organic farming? The consequences considered are many, ranging from the soil to the atmosphere. In this review we use the following list of topics: soil, energy inputs, biological, yields, economic, farm animals, landscape, social and food quality, and use this classification to structure the review.

The main intention, however, is to demonstrate *how* these studies have been carried out, to evaluate these attempts, and to outline how a study might be undertaken in New Zealand.

The review shows that there are a number of styles of study that have relevance to organic farm conversion. There are two broad styles – longitudinal and static/comparative. Some studies directly address the conversion of single properties (or groups of properties) into organic systems and use time series data to draw comparisons between the property in its conventional state and the later organic state. We term these longitudinal studies. The other predominant style does not follow the conversion process directly, but draws comparisons between organic and conventional properties existing synchronically, thus implying that any observed differences would also follow from conversion to organic production. These static/comparative studies utilise a range of styles of cohort construction – from paired farm studies, to broad scale survey research into large

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[3] www.guidetoorganics.com

cohorts. Within these two broad styles of comparison, studies vary from those that address one comparative dimension to those that attempt a comprehensive analysis of many points of comparison between organic and conventional.

There are limitations, however, as to what could be included in this literature review as almost every study ever conducted into organic production could be considered relevant to some degree (for a broader review of organic production systems and land management see BDFGA (2001)). In this review the focus is on primary research, that is, on-farm research that reports on the consequences of any type that emanate from the particular production system. There is secondary research, which does not occur on the farm, and this is reported only where it provides useful insight into the topics considered. Note also that the review covers research published only from 1995 to 2001 obtained using CAB Abstracts[4]. For these years research extending back to 1990 is included because in many research designs their data are reported for five or more years. Thus the review is thorough but not comprehensive. The purpose here is not to provide a definitive review of all literature but to cover sufficient literature to show how research has been done to date and how it can be done in New Zealand in similar or better ways.

Each item is placed in the topic area that best reflects the main findings reported. Occasionally an item is found to be comprehensive in its scope and not easily classified under one topic. These items are put into a separate category towards the end of the review. The main focus is on literature from North America, Europe and Australia. There is a little literature available from developing countries.

By placing these limitations on the literature review, nearly 300 references were assessed to provide the following review. The review therefore provides a rigorous basis for determining an optimum research design for application in New Zealand conditions.

[4] The search strategy was to find all records since 1994 with 'organic' and 'conventional' and 'farms'. Abstracts with either 'acid' or 'matter' were excluded in order to avoid strictly biological research. Is possible that the last exclusion may have removed research on the organic matter effects of conversion.

Chapter 2
Literature Review

2.1 Introduction

This chapter reviews the literature selected and covers a wide range of topics including: soil, energy inputs, biological factors, yields, economics, animals, landscapes and food quality. A catch-all category of studies that are very comprehensive is included before the latter.

The literature is organised by country where possible and presents the most recent research by a given author first. Each section begins with an overview paragraph which highlights the main findings for that section and each section ends with some comments about the methods used in the research.

2.2 Soil

One of the most heavily researched – and critically important – aspects of organic production relates to soil. While the following reviews a number of scientific articles, a more comprehensive review of organic soil science can be found in Blake (2001, in BDFGA, 2001). The research on soil nutrients focuses mainly on the macro nutrients (N, P, K) and particularly on N. Generally, the research indicates that organic farming has lower levels of nutrient inputs. Consequently, there can be lower levels of nutrients in the plants, and lower levels of nutrients available for leaching. It also shows that organic farming can be, but is not necessarily, more beneficial for the soil compared with conventional farming. Organic farming can have a negative effect on nutrient balance. Results vary across organic farms so that in some cases organic farming can have positive effects on nutrient balances even though the average effect is either positive or negative. This finding suggests that there is scope for improving organic methods and that the current state of practice of organic farming is not necessarily an accurate indicator of the future nutrient consequences of organic farming.

An important topic relating to soil and nutrient levels is N loss. Early in the 1990s there was much European research on farming systems and nutrient balances. Kristensen et al. (1995) well illustrate the general viewpoint when they reviewed the results of an international workshop on N leaching, concluding that there was considerable potential for ecological farming systems to offer a viable approach to limit nitrate leaching.

Dabgaard at al. (1998) modelled Danish dairy and pig farming data for organic farms and conventional farms to compare N loss. Organic pig production was found not to help minimise N losses but organic dairy farming was found to help minimise N losses. Fagerburg et al. (1996) measured nutrient levels (taking into account inputs and outputs to determine the net balance) of N, P and K on ecological and conventional farms in Sweden. The farm N balance was increasingly positive on the conventional farm and negative on the ecological farms. The P balance was positive on both systems with a higher surplus on the conventional farms. The K balance was increasingly positive on the conventional farms and close to being balanced on the ecological farms. They conclude that ecological farming is possible without immediate yield reduction but has negative effects on nutrient balances. In Norway, Eltun and Fugleburg (1996) studied arable and forage crop systems on organic, integrated and conventional farms measuring N losses using lysimeters. Results showed that N losses were higher in conventional and integrated arable systems and in the conventional forage systems. Crop rotation and management factors (such as use of farmyard manure), fertiliser level, tillage system and weather were the main factors involved in leaching. In Holland, Werff et al. (1995) studied nutrient balances on three ecological mixed dairy farms on sandy soil. The N surpluses for organic farms were 83 Kg/ha and on conventional farms were 444 kg/ha. The average N efficiency for the three organic farms was 31 per cent and 12 per cent for conventional farms. They conclude that there were possibilities for improvement in farm management to improve ground water quality.

In Germany, a farm in conversion to organic production was studied to assess soil properties at different depths (Kolbe et al., 1999). Over 5-6 years organic production led to a reduction in N input. Results relating to soil nutrient status and pH were analysed to show that organic practices reduced nutrient input and probably increased the soil's ability to conserve nutrients and reduce leaching. Other German studies include Stein-Bachinger and Bachinger (1997) who applied nutrient balance techniques developed for conventional farming to large (230-1,150 hectares) organic farms. Kalk et al. (1997) reported on the N balance on one organic farm and four conventional farms for mixed farming on sandy soils in Germany. N efficiency and N loss potential were affected by site conditions, cropping structure and livestock numbers as well as farm intensity. Schumacher (1996) compared five organic farms with five conventional farms to comprehensively record the nutrient characteristics of the soil, food and manure along with total nutrient balances and energy analysis to conclude that the food supply needed by Germany could be met with organic farming and that organic farming had a more stable ecology.

In Norway, Haraldsen et al. (1999) examined three cropping farms converting to organic production to assess nutrient balances and yields. Three farm types were studied (arable, mixed farming and dairy) each representing a different farming system. For all farms more K was removed than applied but on only one farm was there a significant decrease in soil K status. On two farms, there was a negative balance for P in the soil. On two farms the N balance was close to equilibrium and negative for the other. In France, Simon et al. (1994) assess N balances on 120 dairy farms in three regions. The average N surplus for conventional, low-input and organic farming were 128, 121 and 6 Kg/ha respectively. They conclude that N pollution risks would be better controlled by careful use of organic fertilisers.

In the UK, Brown et al. (2000) assessed topsoil from 30 paired organic and conventional farms across a range of soil types and management regimes in the south of England. The 60 paired farms ranged from grassland to horticultural/arable and purely arable. The results showed that farm types could be most effectively characterised by organic matter, aggregate stability, humic acid, infra-red absorbance and pH and that these differentiated organically and conventionally managed arable and horticultural farms. Pasture farms showed no significant differences between organic and conventional management. Conventional horticultural farms showed the lowest values for soil organic matter, aggregate stability, cation exchange capacity and E4/E6 ratio. Organic horticultural farms had the highest mean humic acid content, infra-red absorbance, air capacity and available water capacity. Infra-red absorbance values showed a clear age trend for humic acid, with older humic acids seen for pasture farms. Management factors deemed most important in differentiating between conventional and organic management included frequent farmyard manure applications to horticultural land and the inclusion of grass leys in arable rotations. Some of the soil measurements are suggested as potentially effective indicators of sustainability for farm systems. Brown et al. (1995) assessed soil organic matter in the south east of England and found that organic arable and horticultural farms tended to have the higher organic matter levels than conventional farms.

In the US (Nebraska and North Dakota), five organic farms and five conventional farms matched for soil type were compared for basic soil properties (Liebig and Doran, 1999a). Results showed that, averaged across farms, organic farms had 22 per cent more organic C and 20 per cent more organic N. At four of the five locations organic farming had soil pH closer to neutral, lower bulk density, higher water holding capacity, microbial biomass and N and soil respiration compared to conventional farms. Soil quality improvements under organic farming were due to use of diverse crop sequences, organic amendments and less frequent tillage. Jones (1996) reported results from the use of a soil quality test kit used on two farm in North Dakota. Results showed potential nutrient losses were highest under conventional management, the conventional farm having the highest soil nitrate and lowest mineral N values. Liebig and Doran (1999b) compared organic and conventional farmers' perceptions of soil quality in Nebraska. The 12 matched pairs of farmers were sent a questionnaire to assess their perceptions of soil quality and these were compared to soil quality indicators. Farmers' perceptions were correct for 75 per cent of the time with no differences reported between farm types. In California, Hasey et al. (1997) compared a kiwifruit orchard converted to organic production against a conventional orchard. Soil analysis showed a trend towards a higher pH and organic matter content over time for the organic system. In 1992, there was a trend for the organic system to have higher NH4-N and lower NO3-N concentrations in the soil. Leaf N concentrations in the organic system were consistently lower than those in the conventional system, but were not deficient. Organically grown fruits were as firm as or firmer than conventionally grown fruits at harvest and 4 months after harvest. Damage from latania scale (*Hemiberlesia lataniae*) and omnivorous leaf roller (*Archips podanus*) was small in both systems, except for scale damage in the organic system in 1992. An economic analysis of the cultural practices showed that the organic system cost almost $720 per ha more than the conventional system. The grower reported fewer repack losses for organically grown fruits in 1992. It was concluded that growing kiwifruits organically is feasible if an economic premium were received.

In Canada, Diiwu et al. (1998) assessed the affects of conventional and no tillage treatments on the spatial variability of soil water properties from samples from one farm. Results showed that variability of the properties on the A horizon for the no tillage treatment was higher than that for the conventional tillage.

In Australia, soil changes due to different management systems for vegetable cropping were examined over 3.5 years (Wells et al., 2000). Five farming systems were examined including three conventional systems and two organic systems. The two organic systems, which received large inputs of compost, had higher soil organic C, microbial biomass, total N, total P, exchangeable nutrient cations, water holding capacity and aggregate stability than the conventional systems. The system with largest mineral fertiliser inputs and most tillage had the highest available P, lowest P sorption capacity and lowest aggregate stability. Consequently, it had the greatest potential to lose sediments and P to the environment. Deria et al. (1996) compared wheat production on eight organic farms paired with eight conventional farms from 1992 to 1994. They found that at four sites yields were similar but at the other four sites the yields were significantly depressed, probably because of the lower levels of P in the soil, later sowing and low N supply. In the organic plots on one site, levels of nitrate N and organic carbon increased while Colwell P and Colwell K were greatly reduced.

In New Zealand, Murata and Goh (1997) examined soil from a pair of farms, one managed conventionally and the other biodynamically. In the biodynamic farm, total carbon and total nitrogen decreased with increasing period of cropping but the reverse occurred under pastures.

These were not shown in soils from the conventional farm, probably due to N fertiliser additions. Nguyen et al. (1995) reported the nutrient budgets for three pairs of conventional and alternative mixed cropping farms. Nutrient budgets for N, P and S on the conventional farms were generally balanced or positive so that the supply of these nutrients was unlikely to be limiting production. Nitrogen budgets were positive at all three alternative farms with biological N2 fixation accounting for most or all of the N input. One alternative farm had positive P and S budgets because of additions of compost, phosphate rock and elemental S. By contrast, at the other two alternative farms, net removal of P, and in one case S, occurred. In the other case, the S budget was balanced by one application (per rotation) of S fertilizer to the pasture. At these two sites, concentration of grain N, P and S were lower than those at conventional sites and pasture herbage P and S concentration were below recommended critical concentration. Levels of total S and P and available P in soils were also lower on the alternative than conventional farms. Production on these alternative farms was relying on soil reserves of P and S, and additions of P and S would be required in the future to sustain current production levels. Organic C content and arylphosphatase, arylsulphatase and urease activities tended to be higher under alternative than conventional pastoral management. This was attributed to the longer pastoral phase under alternative (3-4 year) than conventional (1-2 year) management resulting in a small build up of organic matter. However, organic C content and enzyme activities were similar under conventional and alternative systems during the arable phase suggesting that conventional management had no adverse effect on soil biological activity.

Some soil studies have taken a more comprehensive approach and measured a number of soil characteristics. Hansen (1995) reported the effects of manure treatment and soil compaction on plant production on a dairy farm in conversion to organic methods in Norway. The different methods of manure treatment had little effect on yield. Soil compaction from tractor traffic decreased the average dry matter yields from 9.0 to 6.6 tonnes/ha/year. Soil compaction reduced air-filled soil space and reduced the mass of earthworms. The conclusion reached was that it was more important to avoid soil compaction than to increase manure rate.

The research methods used include modelling but mainly they directly compare measurements on the different types of farms often for a number of years. Sample sizes were low and most used less than five farms of each type. There were five studies of organic farms in conversion and 16 studies that involved comparison between organic and conventional farms. Of these 16, eight were unpaired and six were paired. Two studies compared different techniques on the same farm.

2.3 Energy Inputs

The energy research consistently reports lower levels of energy used in organic farming. A principal factor is the high energy component of manufactured fertiliser used in conventional production.

Refsgaard at al. (1998) and Halberg at al. (1999) examined energy used on conventional and organic dairy farms in Denmark on sandy, dry sandy and clay soils. They used system modelling from farm data. The first study found conventional crops had higher yields but required more direct energy compared to organic crops so that conventional yields were not sufficiently high to compensate for the extra energy used. Sensitivity analyses of irrigation and fertiliser use found that better energy utilisation may be obtained with intermediate levels of fertiliser use. The second study reported that while the consumption of diesel fuel per hectare was similar on each type of farm, the energy consumption per unit of production was lower for organic farms due to the high indirect energy costs of the conventional inputs. Costs were high on the dry sandy soils regardless of farming system. Lunzer (1997) tabulated the energy inputs for organic, biodynamic and conventional farms in France, Germany and Switzerland. Data were developed for the inputs of fertilisers, plant protection, soil cultivation, sowing and machinery use and for energy outputs. Results showed that the energy input to output ratios were most favourable for organic systems. In Switzerland, Alfoldi et al. (1994) measured energy inputs for a seven-year rotation of potatoes/winter wheat/beetroots/winter wheat/barley/ two-year pasture managed using bio dynamic, bio-organic and conventional systems. Except for potatoes, the biological systems used between 16 and 38 per cent less energy for one tonne of crop.

In California, Gristina et al. (1995) conducted field trials of the energy inputs for vegetable and grain crops. The organic system was 60 per cent more energy efficient then the conventional system. In New Zealand, Nguyen and Haynes (1995) measured energy and labour efficiency on three paired alternative (organic or biodynamic) and conventional cropping farms. They found that over the entire rotation, the mean annual energy input was considerably lower under alternative than conventional management. Labour input was higher under alternative management for individual cereal crops but mean annual labour inputs over the whole rotation were slightly lower under alternative than conventional management.

The small number of studies on energy all incorporated comparisons of organic and conventional farms, using small sample sizes.

2.4 Biological/Biodiversity

There have been a substantial number of studies reporting on the consequences for on-farm biology and biodiversity relating to conversion to organic production. We classify them into the topics of pasture, fungi, birds, arthropods and 'other'. The pasture research shows that definite changes in either species number or density can be attributed to organic management. Similar results were found for micorrhizal fungi. Research on birds reports high numbers and types of species on organic farms. Research on arthropods shows similar findings but there were more reports of differences between types of farming which were not statistically significant.

Pasture. Petterson et al. (1998) reported the botanical and chemical composition of grass/legume forage from organic and conventional farms in Sweden. Traditional and new techniques of chemical analysis were used and the data were subject to multivariate analysis. There were significantly higher percentages of clover in organically grown leys.

In Germany, Freben (1997) reported on species diversity in grassland on seven organic farms at three sites and compared those to nearby conventional farms. The number of species on organic farms was greater than on conventional farms although it was often below that of a typical grassland plant community before intensification. The conclusion was that the quality of pasture on organic farms depended on fertiliser use before conversion.

In Austria, Schatz (1997) compared species composition on ten conventional and ten organic farms and reported that on organic farms the less prominent grasses and legumes were more frequent. The conventional farms with high N turnover, favoured tall grasses at the expense of shorter grasses. Potsch (2000) found higher incidence of docks in pasture for biologically managed farms compared to conventional farms.

In Switzerland, Schreiber et al. (1996) conducted vegetation surveys on grain fields, meadows and natural grasslands for 46 organic, integrated and conventional farms. The organic grain fields had twice the species diversity compared to the other systems. In meadows and pastures no differences in species diversity were found. In the grain fields endangered species were found more frequently.

Fungi. Ryan et al. (2000) examined micorrhizal fungi on biodynamic farms and conventional farms in Australia. Ten pairs of dairy farms were studied, each pair consisting of adjacent farms. The conventional farms received significant quantities of fertilisers. Analysis of miccorhizal levels in white clover, ryegrass and paspalum was lower on the conventional farms. In the UK, Eason et al. (1999) used spores from conventional and organic farms in a series of inoculation trials on 24 sites on 13 farms. They found that spores from organic farms produced significantly greater yields compared to spores from conventional farms. Similar results are reported by Scullion (1998). In Canada, Kerle et al. (1996) surveyed micorrhizal species in two adjacent areas in Minnesota, one which had received no fertiliser or herbicides in the last 25 years and an experiment station which had received such inputs. The organic farm had greater species richness (13 species compared with ten). They concluded that management practices influence fungal species composition through biotic and abiotic factors.

Birds. Shutler et al. (2000) examined the avifauna effects of tillage versus chemical weed control in Canada. The experiment had four treatments including conventional, minimum tillage, organic farms and wild sites. Species count data (density and diversity) showed small treatment effects could be ascribed to differences between conventional and minimum tillage farms but larger differences were found between wild sites and all farms. For our purposes this study shows that the common organic practice of minimum tillage had positive effects on the number and types of birds. In North Dakota, Lokemoen and Beiser (1997) observed seasonal bird use and nesting activity in fallow, sunflower and wheat fields on organic farms and conventional farms. Spring bird densities were highest on the minimum tillage fallow field. The mean number of nesting species and mean nest densities were higher on minimum tillage and organic farms than on conventional farms.

In England and Wales, Chamberlain et al. (1999) surveyed field boundaries and fields over three breeding seasons to assess size and diversity of bird populations. Twenty pairs of organic and conventional farms were observed. Results showed species diversity was higher on organic farms in one breeding season. Eight of 18 species showed significantly higher density on organic farms. Data analysis showed that components of habitat structure were important in explaining bird differences between farm types. A similar conclusion is supported by Fuller (1997) who reports briefly that comparisons of organic and conventional production on Danish and British farms show that bird populations are generally higher on organic farms.

Arthropods. Alverez et al. (2001) examined the prevalence of arthropods on winter wheat for conventional farms, integrated farms and organic farms in England. Generally they found that organic farms and conventional farms did not differ significantly in terms of community composition. However, some species were consistently, but not significantly, more common on conventional farms than on organic farms, and some species were consistently but not significantly more common on organic farms than conventional farms. Also in the UK, Moreby and Sotherton (1997) measured insect densities and species in winter wheat fields on organic farms and neighbouring conventional farms. There were more broad-leaved weeds and more plant species on organic farms but higher densities of aphids and their predators on conventional farms. Although higher densities of insects were found on organic farms many of these were not significantly different from levels on conventional farms. Moreby (1996) studied weed and insect densities on 56 fields in 1990 and 62 fields in 1991 and found four out of the five bug groups studied (hemiptera: heteroptera) were more numerous within organic fields then on conventional fields in both years. But differences were statistically significant in only one out of ten comparisons. Feber et al. (1997) took butterfly transects on eight organic farms and eight conventional farms (paired) in 1994. Species types and abundance was measured to find that significantly more non-pest butterflies were recorded on organic farms than on farmland, and more non pest butterflies were recorded on the uncropped boundary habitat than over the crop edge habitat of both systems. In contrast, there were no significant differences in the abundance of two key pest species over the two systems.

In Germany, Hussein and Hussein (1999) found that conversion to organic methods on one farm had positive effects on beetles. Basedow (1998) examined species composition and frequency of spiders on one organic farm and two conventional farms. Results showed that spider frequency and density did not vary across sites but species number did. There were 20 species occurring exclusively on the organic farm. Basedow (1995) reported the results from three sites in Germany. The data show that ecological farming in wheat growing areas led to a high abundance and diversity of arthropod fauna compared to that found on conventional farms. Both insecticides and herbicides exert a negative effect on fauna. The author notes that these results are confirmed in other studies in Europe but on sandy soils findings can deviate from those reported.

In Sweden, Bommarco (1998) studied the characteristics of a predatory beetle on two conventional farms and three organic farms. Fecundity and body size were correlated with the degree of landscape heterogeneity. Localities with small fields, high perimeter to area ratios and high percentages of perennial crops harboured beetles that were larger and had a fecundity almost three times greater than beetles from localities with low spatial diversity.

Another method for examining the effects of organic versus conventional methods takes an experimental approach rather than an on-farm approach. These studies use laboratories or special situations in which practices are applied experimentally. For example, Phelan (1997, 1995) determined that maize grown in soil from organic farms had a lower number of eggs laid by the European Corn Borer (*Ostinia nubililas*) compared to maize grown in soil from conventional farms (three paired comparison). Plant material balance appeared to explain the different leaf preferences. These results were similar to Whelan et al. (1996) who used the same experiment to find that soil-fertiliser combinations producing the lowest protein levels were those whose plants received the greatest number of *Ostinia nubililas* eggs. They suggested that differences in maize susceptibility is partially mediated by plant nutrient balance and that optimal balance is more likely to be found in organically managed soils because of the inherent property of reducing variation in mineral availability in those soils. In California, Letourneau et al. (1996) examined the link between management practices (including organic and conventional), tissue N and herbivore damage. They took samples of tomato plants from 20 subplots from 17 commercial farms. Tissue N varied widely both within fields and among sampled farms, however damage to tomato foliage did not increase with increased N content of the crop.

Others. Brown et al (1999) have examined the effects of different farming practices on small mammals using a series of long-term studies (1992 to 1998) on arable farms in England. They found that margins and predator strips are important as reservoirs for most species of small mammals. Blakemore (2000) reports on the ecology of earthworms on farms under organic and conventional regimes. Earthworm populations and soil properties were compared at a farm in Haughley, Suffolk, UK, that has maintained either organic, mixed conventional or stockless intensive arable management regimes on different parts of the farm since 1939. Significant differences in both the earthworm populations and soil properties were found between treatments. Earthworm populations were 178.6, 97.5 and 100 per m2 for organic, mixed and stockless fields, respectively. The qualities of the soil on the organic farm were more favourable than the stockless soil and the mixed field was intermediate. Laboratory studies with choice chambers offering the three field soils showed that earthworms (*Lumbricus terrestris*) preferred the organic soil (96 worms) to the mixed and stockless soils (75 and 73 worms, respectively).

The methods used for the arthropod research are wide ranging. There are laboratory experiments using soil obtained from organic and conventional farms, studies of organic farms only, and comparative studies. The latter include some studies with large sample sizes presumably because it is relatively easy to collect specimens across many farms. Generally, it seems that studies of biological effects need to have distance between organic and conventional sites to avoid cross treatment contamination. In contrast, soil research can usefully use neighbouring farms in order to have matched soil types since there is less scope for influence from one farm to another.

2.5 Farm Animals

Of the animal studies, dairy cows have received most attention. Perhaps the positive findings regarding production and profitability have supported conversion amongst dairy farmers and this has stimulated research on the animals themselves. A popular topic has been mastitis and the general finding has been that mastitis levels are similar on organic and conventional farms.

Dairy cows on organic dairy farms in Switzerland have been studied to assess the hypothesis that their nutritional status was insufficient (Trachsel et al., 2000). Body condition was scored in winter and summer for the cows on 152 farms. Milk production was 5-12 per cent lower than average but analysis of the scores showed that most cows on organic farms had optimal body condition scores and therefore an adequate nutritional status. There were energy and or protein deficits in winter. This study takes detailed data from a large sample of organic dairy farms and compares them with industry average.

A number of studies have studied mastitis in cows on organic farms. Hovi and Roderick (2000) report results for a two-year study of organic dairy herds in England and Wales. Results show that the mastitis risk in cows on organic farms was no greater than in cows on conventional farms, some organic herds had high levels over the dry period. Organic herds had higher somatic cell counts. Similarly, Weller and Bowing (2000) assessed the health status of cows on ten dairy farms in England and Wales from 1995 to 1998. In this study the overall health status of the cows was measured using mastitis incidence, somatic cell counts, lameness, metabolic disorders. No long-acting antibiotics were used during the dry period, and many cases of clinical mastitis during lactation were treated without antibiotics. The incidence of clinical mastitis was no higher than in conventional herds. However, on some farms there were high levels of mastitis that resulted in price penalties. For an earlier period, Weller and Cooper (1996) reported that on 11 converting dairy farms in England and Wales there were no major health problems. Clinical mastitis was the main problem on all farms. The incidence of lameness was lower on conventional farms.

Svensson et al. (2000) examined parasite control in organic farms and conventional dairy farms in Sweden. They surveyed 162 farms of each type to learn about parasite control practices. They report different techniques are used and suggest that organic farms have greater problems with parasite infections than conventional farms.

In Germany, Horning (1997) assessed the effects of dairy cow housing on 60 farms, one half of which were organic and the other half were conventional. Scores were developed for three behavioural aspects of housing (lying down, feeding and walking). Results showed that scores for organic farms were significantly higher than those for conventional farms. In Denmark, Vaarst et al. (1998) examined sole disorders in dairy cows and compared the records from 1,842 claw trimmings from seven organic farms with six conventional farms. Results showed a number of factors (time of year, breed, body weight) were associated with the presence of sole disorders but none of these included type of farm.

Olsson et al. (1996) reported pig management on three organic farms in Sweden. Outdoor management resulted in higher mortality, lower growth rate and leg disorders. They conclude by recommending ways to improve organic pig management.

Most of the studies on the effects on animals have used comparative methods and large sample sizes.

2.6 Yields

This section reports those studies of yields that have not gone on to consider the economic consequences of changing yields (the topic of the next section). As such they are rather incomplete but do provide the first part of any economic assessment of organic production. The yield research shows, generally, lower yields across a range of types of organic farming but occasionally organic yields are the same as conventional production or higher. In the case of dairy farming there are a number of studies reporting some elements of production (mean milk yield, milk fat, annual milk yield) that are higher on organic farms.

In Switzerland, Dubois et al. (1999) compared yields for biodynamic, organic and conventional farms over three courses of a seven-year rotation of potatoes/winter wheat/cabbages or beetroot/winter wheat/grass-clover. Nutrient inputs in the two organic systems were about 50 per cent lower than the conventional system. Yields of potatoes declined to 70 per cent then to 50 per cent of the conventional yield. The other crops also decreased in volume. In terms of energy input, the organic system was higher than the conventional system for potatoes but lower for winter wheat and grass/clover.

On Denmark, Kristensen and Kristensen (1998) compared milk production on 13 organic farms and 18 conventional dairy farms. They used data from intensive observations over a three year period which were used to develop a simulation model. In the organic system peak milk yield per lactation was lower than for the conventional system while annual milk yield was higher, explained, they suggest, by the more even intake of roughage through lactation. They conclude that if conversion to organic farms is followed by careful attention to pasture management and preventative mastitis management the effect on feed intake and yield will be reduced. Halberg and Kristensen (1997) used data from organic and conventional mixed dairy farms in Denmark to estimate that the yield difference of 21-37 per cent for grain crops and 12-18 per cent for fodder beets and grass/ clover. They develop a method to correct for time of year and location by using a linear statistical model to simulate potential yields. They suggest that nutrient levels explain the lower yield on organic farms.

In Sweden, Jonsson (1996) reported the production levels from an organic dairy herd and a conventional dairy herd (about 50 cows in each herd). Results showed that mean herbage yield was 14 per cent lower on the organic farm and the barley crop five per cent higher. For milk, the mean milk yield and milk fat content were three and one per cent higher respectively and milk protein was five per cent lower in the organic herd. Herd health results were the same on both farms.

In the US. Clark et al. (1998) examined pest management on conventional, low input and organic tomato and maize systems in California. Generally, they found that arthropods, pathogens and nematodes had a small influence on yields. In contrast, weed abundance did affect yields. Pesticide use could be reduced by up to one half in maize with little or no yield reduction. Mechanical cultivation instead of herbicide use in maize could reduce pest management costs, but not for tomatoes.

Drinkwater et al. (2000) examined weed control and management of legume-based grain production on an experimental farm. The experiment was run over seven years. Comparable yields were achieved for organic farms (cultivation and use of green manure) and conventional farms (herbicides and N fertilisers). Gristina et al. (1994) measured yields for a number of vegetable and grain crops in California grown under organic, low input and conventional systems. Each system had some crops which had the highest yields. Overall, they conclude that the conventional system was most productive and the organic system least productive but the differences were not large. The organic system has the most stable yields.

The yield research has used comparisons of organic and conventional farms. Three of the studies have reported yields over three or more years.

2.7 Economics

Economic studies of conversion are the most numerous among the abstracts reviewed in this Research Report. By far the majority of studies are from Europe. The general and consistent finding is that net profits or gross margins are higher for organic production. Two main factors are at work here: lowered input costs and the presence of premiums or subsidies. A large number of products are considered, ranging from horticultural crops (tomatoes, grapes, olives) to animal (cows, pigs), arable (cereals) and mixed farming. The issue of premiums receives different treatment across the authors. In some cases premiums are available and in some case they are not. For the former, some authors include them in their calculation while others consider them to be ephemeral and exclude then from analysis. Frequently found is the fact that organic farms are smaller than conventional farms and this may affect profitability since they are less able to obtain economies of scale.

Marra and Kaval (2001) compiled 321 separate studies of the profitability of organic or no till grain cropping systems compared to conventional systems in North America. Results showed that the relative profitability of organic production was, on average, higher for maize and grain sorghum and for research conducted on experimental stations. Dobbs (1988) examined price data for organic and conventional foods in the USA focussing on maize, soybeans, wheat and oats to find that some certified organic grain and soybean commodities have had higher prices than the same commodities produced conventionally. Dobbs and Smolik (1996) compared one organic farm and one conventional farm on the western edge of the corn belt over an eight-year period. They found that earnings on both farms were acceptable but the conventional farm was more profitable on average compared to the organic farm when organic premiums were excluded. Gliessman et al. (1996) compared a strawberry crop on conventional and organic land in California over three years. They found that the organic crop was slower growing, had lower yields, and increased labour requirements but there was little economically important pest damage, no nutrient deficiencies and an increase in predators and beneficial nematodes. Although yields were down, price premiums permitted favourable returns. Brumfield et al. (1995) examined the profitability of fresh tomatoes using organic, IPM and conventional methods grown in the Rutger's University research farm. Results showed that organic plots had higher chemical costs, higher labour costs and lower net returns than the conventional or IPM systems, while the latter two had similar net returns. For grape production, White (1995) examined growing methods and costs over five years to conclude that grapes could be grown successfully using organic methods although at a higher cost compared to conventional methods. He concludes that premiums would be necessary to make organic production economically successful.

In Canada, Ogini et al. (1999) compared eight organic dairy farms with 120 conventional dairy farms. The farms types were well matched having similar scale of operation and levels of milk production. The organic farms yielded 60 per cent more net farm income. Pellerin and Allard (1998) compared the financial results between 1990 and 1995 from organic and conventional farms in Quebec and found no difference in size or profitability. Veterinary costs were significantly lower for organic farms. In contrast, Burgoyne et al. (1995) studied 336 conventional farms and 16 organic farms in Quebec and reported that organic farms had economic and financial performance at least as good as the highest yielding conventional farms. Stonehouse (1996) compared organic, low input and conventional farms in Ontario. These were mixed farms cropping maize, autumn cereals and beans. Each farm type had similar resource endowments but the conventional farms were largest and the organic farms were the most diversified and smallest. Total direct production costs were lowest for organic farmers. Gross margins were highest for organic farms for all three crops and lowest for conventional farms. Stonehouse et al. (1996) reports similar results, specifying that they surveyed 25 farmers, including nine conventional, nine using reduced inputs and seven organic farmers.

For the UK, MacNaeidhe and Fingleton (1997) examined farm profitability for one farm over three years to find a 58 per cent improvement in gross margin. Using a similar method Higginbotham et al. (1996) reported on profitability on one farm as it converted to organic farming. Results were varied and they conclude that care is needed when comparing only one year's results. More generally, Colman and Tinker (2000) review the UK farming system and compare the profitability of conventional and organic farming. They find that the major categories of organic farming (dairying, cropping and mixed farming) were more profitable per hectare, on average, than conventional farming. More generally, Reganold at al. (1995) summarise data from previous studies to show that biodynamic farming generally had better soil quality and was just economically viable on a per hectare basis compared to their conventional counterparts.

For Europe, Offerman and Nieburg (2000) review data from 15 EU member states and from Norway, Switzerland and the Czech Republic to conclude that profits on organic farms were on average comparable to those on conventional farms. They assess the effect of the 1992 CAP reform on the profitability of organic farms and find that the policy has ensured the relative competitiveness of organic farms.

Genen (1999) assessed 15 vegetable farms in Holland and compared results with conventional farms data. Results showed that there were higher production costs for organic farms. Although there was discussion of the factors influencing profitability, there was no consideration of net profitability. Berentsen et al. (1998) developed a linear programming model for the effects of conversion on dairy farms for an extensive and an intensive farm. Results showed that the extensive farm benefited from conversion while the intensive farm lost income. When environmental legislation was introduced into the model, the intensive farms lost more income than the extensive farms. Sensitivity analysis showed the assumptions about milk yield per cow and milk price were crucial for the economic results of extensive farms.

In a review of organic farms in Germany (Leithold, 1999) shows similar findings: yields for organic crops were lower than for conventional crops but incomes were higher. Some studies fail to examine the effect of premiums for organic products. For example, Wagner (2000) assesses quality of pig meat and costs of production for pigs fed conventional food compared to pigs fed with legumes grown on the farm. The conclusion reached was that organic farms have higher costs. Nieberg and Schultse (1996) reported the profitability of 107 farms converting to organic production. A comparison of the last year of conversion with the first four years of organic production showed that profitability depended on the extensification premium and the marketing possibilities for organic products.

In Switzerland, conventional, integrated production and low input production were compared on one farm. Over the seven years of study, arable crop yields were lower for the two non-conventional systems but net profits were comparable or better because of the direct payments from the Swiss government. Hilfiker (1998) assessed the performance of organic farms supported by five government programmes introduced in 1995. Data from 150 eco-pilot farms from 1993 to 1996 showed that yield on integrated farms were slightly lower than those on conventional farms while those from organic farms were considerably lower. In recent years organic farm results have been better because of subsides and premiums. Hilfiker (1997a) reported similar results from pilot studies of cereal production. From integrated farms yields were a little less than conventional systems while those from organic systems were much less, but yield losses were more than compensated by direct payments and higher product prices. Hilfiker (1997b) compared farm records for organic and conventional farms from 1994 to 1995 and concluded that integrated and organic farms made heavier demands on labour but had slightly higher earnings per farm and per worker, as well as ecological advantages, compared with conventional farms. Regev et al. (1997) took a different tack in their economic analysis of risk in organic and conventional farming. Comparison of organic and conventional wheat growers showed that while yield variance is lower, revenue variance is higher on conventional farms. This occurs because the latter are protected from market risks by guaranteed prices, while the prices for organic wheat fluctuate highly. They conclude that chemical pesticides and nitrogen may be risk-increasing inputs. Hofstetettler (1994) compared 36 biological farms with 36 conventional farms, matched for production zone, production structure and approximate size. Results were also compared with 1,815 valley farms. Incomes from the bio-farms were lower than conventional farms but this was partly because the bio farms were smaller and also had smaller arable area than their controls.

In Denmark, Folkmann and Poulsen (1998) developed static farm budget models for the four main enterprise types (crop, dairy, pigs and poultry) on farms over 100 hectares in size. Results showed that on average organic farms perform at around half of the physical level of conventional farms but profitability at 1997 prices and subsidies was better for organic production. In Sweden, Helander et al., (1997) compared ecological, integrated and conventional arable farms from 1991 to 1995. Results showed lower yields on the ecological farm. By 1995, net surplus was better because of higher arable payments and higher demand. Yields from the integrated farm were similar to the conventional farm but economic results were not as good. Lundstrum (1997) analysed the marginal economic effects of conversion to organic milk production in Sweden taking into account environmental effects. The conclusion is that a social benefit is demonstrated.

In Austria, Eder (1998) reviewed the farm sector for 1997 to report that 18,363 farms occupying 256,000 hectares were in organic production. A sample of organic and conventional farms showed that organic farms had slightly lower returns balanced by lower costs and achieved better earnings per farmer and per person than conventional farms.

In Finland, Koikkalainen (1996) examined the relative profitability of organic and conventional farms for all main production types over a five-year period. Cereal farms and cattle farms were more profitable in organic farming at the given support level, while for large farms and vegetable farms organic production was not viable.

In Italy, Pampana et al. (2000) compared conventional production, modified conventional production (reduced fertilisers and pesticides) and organic production. Maize/wheat or soybean production on two farms over two years was examined to show that while conventional production was 17 per cent higher, economic benefits were satisfactory for organic production and highest for modified conventional production. For olive oil production, Chorri et al. (1996) compared three organic farms with 23 conventional farms and found that the economic results were 'interesting' despite lower output volumes. Chiorri et al. (1995) were more definite saying that for olive growing in Umbria, a three year study showed that the organic farms had higher variable costs but lower fixed costs, and overall costs were lower by 33 per cent. Santucci (1996) compared the economic performance of 19 organic farms in Umbria against data from 349 non-organic farms. Productivity was 20 per cent less on organic farms but net farm income per family member was higher.

The theme of lower yields but higher profits is found in studies of organic farms in developing countries. For example, Malik et al. (1998) report this finding in the Indian Punjab, and Harkaly et al. (1997) report it for coffee growers in Brazil.

Some studies have assessed the economic impacts of widespread conversion to organic agriculture. In Denmark, Wymen (1998) used a four region, partial equilibrium model of agriculture to consider the effects of widespread adoption of organic practices. Results suggested that if less than 25 per cent of farmers converted then sector incomes would remain the same, but considerable loss of income would occur if a high percentage of farmers converted.

Another approach to economic studies is to model the consequences of different production systems. For example, Finco and Prestamburgo (2000) compared conventional farms with the type of farming required by EEC Regulations 2078/92 and used mathematical modelling to find that the latter would not be economically viable. This study was based on a simulation of organic farming and attendant assumptions about the environmental consequences of each farming system. Haataja (1998) modelled four management systems for dairy, beef and pig farms in Finland. Results showed that organic farms had extra costs compared to conventional farms. In Italy, dairy farming under organic farms and conventional farms was modelled to simulate environmental, economic and technical factors (Pacini et al., 1998). The model showed that organic farms achieved an economic efficiency level equal to conventional farms due to the favourable price for organic milk. In Holland, Berentson et al. (1998) modelled dairy farm conversion to biodynamic or organic systems. Results showed that for extensive farms, conversion was beneficial but the intensive farm lost income.

To match the large number of economic studies, there is a wide variety of methods that have been used. These methods ranges from studies of single farms to large sample surveys. Modelling is also used, either for the agricultural system of one country or at the level of the farm. Economic studies lend themselves to comparing data from organic farms with available data from conventional farms since in many countries good economic data are available.

2.8 Landscape

Research on landscape effects of farming are relatively recent and most of them stem from one particular conference. Attention is given to the development of instruments and criteria to evaluate the landscape effects of farming. The general finding is that organic farms are rated more highly than conventional farms.

MacNaeidhe at al. (2000) developed a list of 86 parameters to measure the nature and development of landscape in Ireland and applied these to two organic farms and to two conventional farms. Application of the parameters showed that organic farming has an overall positive effect. Conventional farming can have some positive environmental effects but typically has neutral or negative effects. In a more detailed study of landscape evaluation and organic farming, Kuiper et al. (2000) included non-expert and expert values and focused on the development of appropriate assessment criteria and a checklist. The checklist was implemented on organic farms and adjacent conventional farms in nine regions in Europe. The authors focused on the development of the method and briefly report initial testing. One test site was Crete where Stobbelaar et al. (2000) evaluated two organic farms using abiotic, social and cultural criteria and compared the scores for each farm. They concluded that the larger organic farm performed better than the smaller. Some comparisons to surrounding conventional farms were made. The authors concluded that the organic farms perform 'pretty well'. Another test was in Holland. Hendriks et al. (2000) focused on eight horticultural farms and assessed visual quality in terms of landscape coherence. Reference images were developed to assess the quality of farm appearance. They found that in general organic farms had better landscape quality than conventional farms.

The landscape research has focussed on the development of assessment criteria and applied these to a small number of farms.

2.9 Social

The studies of farmers mainly cover attitudes although there is one study of farmers' and workers' health. Generally, organic farmers have distinctive attitudes, including more positive attitudes to the environment, lower input techniques, are younger, their farms are smaller and a higher proportion of total income is from off farm. Some of these criteria are in direct contrast to preliminary work in New Zealand by Fairweather et al. (2001) which showed no age or educational differential. The common factors were the smaller farm size, adoption of low input techniques and more positive attitudes to the environment.

Morgan et al. (2000) argue that conventional farmers are in a food chain which relies on intensive inputs and tends to distribute knowledge back to input suppliers. The organic food chain distributes knowledge back to the farm as farmers relocalise the understanding of the production process and become 'knowing agents'.

In a detailed study of human male fecundity, Thonneau et al. (1999) examined effects of exposure to pesticides on the amount of time needed to conceive for farmers and agricultural workers in France (n=362) and Denmark (n=449). Results showed no relation between time to pregnancy and male exposure to pesticides. This study was not based directly on comparison of farming systems but it is likely that farmers and workers not exposed to pesticides were working on organic farms.

In Denmark, organic farmers have been compared with conventional farmers in a review of the organic sector (Statens Jorbbrugs, 1998). Results show that organic farmers were eight years younger than conventional farmers. Organic farms have higher non-farm income. Survey analysis such as this document the characteristics of the farms and farmers under different management systems and indicate that these changes are a product of the process of conversion from conventional to organic farming.

Kuhnert (1998) surveyed 200 organic farmers and 200 conventional farmers in Germany to establish the form and extent of their use of direct marketing. Comparisons were made to survey data from another 220 farms. The article reported on the potential for direct marketing.

In the UK, Burton et al. (1999) surveyed 237 horticultural producers to find that organic producers were younger, had smaller enterprises, and were more likely to be female than conventional farmers. Registered and unregistered organic farmers were found to have different characteristics.

Young (1998) examined factors which determine choice of production system assessing results from surveys of 86 organic and 151 conventional farmers in the UK, Spain (97 organic farms and 125 conventional farmers) and Brazil (53 organic farmers and 147 conventional farmers). Newer farmers were more likely to adopt sustainable practices and different information sources were used by organic and conventional farmers.

In Canada, Egri (1999) surveyed 118 organic farms and 85 conventional farms to find significant differences in attitudes towards organic farming and the use of synthetic agrochemicals. In the US, Fernandez et al. (1998) surveyed about 300 organic farmers and compared results with data from about 6,900 conventional farmers. Organic farmers were younger, better educated, had less farm experience, were less likely to have grown up on a farm and had small farms on average. McMann et al. (1997) compared the results from 25 detailed interviews with organic farmers with data from a 1991 survey. Organic farmers had greater concerns about long-term sustainability, had greater willingness to incur present risk to gain future benefits, and scored higher on a measure of conservation practices. Also in the US, Duram et al. (1997) assessed ecological attitudes among farmers on 50 irrigated farms, 45 dry land farms and 45 ranches using both questionnaires and interviews. Factor analysis of the data led to the development of a continuum of agro-ecologial behaviour from reactive to proactive characteristics which it is argued is better than dichotomous categories because there is a spectrum of farm and farmer characteristics. Lockeritz (1995) interviewed 13 organic and 13 conventional growers in Massachusetts to report that organic farms were smaller than conventional farms and provided a smaller proportion of farm income. Organic farmers had entered farming more recently than conventional farmers and were strongly committed to organic methods.

In Australia, Rickson et al. (1999) compared the attitudes of 156 organic farmers with 204 conventional farmers. Results showed that organic farmers experienced higher levels of work satisfaction and endorsed the alternative agricultural paradigm more strongly than conventional farmers. There was no pairing of farms or control over the comparison. It is possible that organic farms are 'pre selected' to have higher levels of work satisfaction or that they rated work satisfaction highly in order to rationalise their approaches to farming.

Research in New Zealand by Fairweather et al. (2001) showed that primary producers who were organic, or strongly desired to be organic, tended to be horticulturalists, with a positive attitude to the environment, and a lower than average gross farm income. They were not, however, distinguished by age or by level of education.

The studies of social characteristics have all been based on surveys. We have found no social research that uses methods appropriate for small sample sizes such as ethnography or participant observation. These studies do exist, but not in the journal form available through CAB Abstracts. There is scope for more detailed studies of the deeper beliefs and worldviews of organic and conventional farmers and for analysis of their behavioural and family dynamics.

2.10 Comprehensive Studies

There are some studies which are multi-dimensional – attempting to follow several different aspects of farm activity in conversion, or comparison between organic and conventional farms.

Cobb et al. (1998) review one farm in the UK that converted to organic methods over the 1986 to 1996 period. They report that conversion leads to reduced air and water pollution and increases the numbers of butterflies and spiders. Gross margins fall then increase once full conversion is complete. They estimate that the social benefits of conversion are £75 to £125 per hectare per year. Similarly, Cobb et al. (1999) integrate the study of soil condition, biodiversity and social-economic effects of conversion by studying one farm. They found evidence of increased species diversity, and improvement in profitability. They also examined how variation in management practices influenced the notion of on-farm and off-farm environmental consequences.

In California, Drinkwater et al. (1995) compared organic and conventional systems of tomato production and measured below-ground parameters, agronomic indicators (biomass, fruit yield, insect pest damage) and community level indicators (arthropod activity, and soil microbial activity and diversity). The two production systems could not be distinguished on agronomic criteria but differences were found for soil, plant, disease and diversity indicators. N mineralisation potential and microbial and parasitoid abundance and diversity were higher on organic farms. They concluded that biological processes compensated for reductions in the use of synthetic inputs.

In South Dakota, Smolik et al. (1995) assessed the agronomic, economic and ecological performance of organic, conventional and reduced tillage cereal farms. They measured soil erosion, pollution potential, energy use and farm size over a seven-year period for two main cropping systems. Results showed that in Study 1, the alternative system was the most productive, while in Study 2, the alternative system had lowest agronomic production but its economic performance was similar to the conventional system. Year to year variability in production was lowest on the alternative system, and its energy efficiency was highest. In Study 1 the potential for groundwater pollution by nitrogen was lower than for the conventional system.

They conclude by noting that the alternative systems are more sustainable in that agro-climatic area.

The comprehensive studies confirm the findings already reported. Two of them apply their comprehensive approach to just one farm. Both of the remainder conclude positively about their alternative systems. These studies illustrate the wisdom of including many variables in any study in order to develop a comprehensive evaluation of farm conversion.

2.11 Food Quality

The area of food quality is one of the most extensively researched – and relatively inconclusive – surrounding organic agriculture. A recent comprehensive review of studies by the Soil Association (UK) (Heaton, 2001) suggested some broad leanings in favour of organic food having better nutritional status, but the results varied widely across foods. The following studies show the difficulties of studying organic food quality.

Sundrum (2001) in a review of findings relating to organic farms and conventional farms states that there is little evidence for a system-related effect of organic farming on product quality. Zangerl et al, (2000) studied 262 organic milk products from farms in Austria and found sensory defects, excess water content, moulds, and the presence of E coli. However, they conclude that there were no great differences in these results compared with those from surveys of conventional farms. Jahreis et al. (1997) studied milk samples taken from conventional (indoor feed), conventional (grazing in summer) and ecological (grazing in summer) farms. Milk concentrations of conjugated linoleic acids (CLA), trans vaccenic and other isomers of milk fatty acids were determined. There was substantial variation (0.26 to 1.14% of total methyl esters) in the CLA content of the milk; this variation was also season-dependent. The lowest percentage of CLA (0.34%) was found in the group fed only on fermented roughage and concentrates and the highest (0.80%) in the ecologically produced milk fat. The concentration of CLA and vaccenic acid was positively correlated. It was concluded that the percentage of CLA in milk products can be increased through a suitable dietary regimen.

Jorhem and Slanina (2000) assessed whether organic cultivation systems reduced the level of cadmium (a potentially harmful metal) and other trace elements in food crops in Sweden. Rye, wheat, carrots and potatoes were harvested from organic farms and from neighbouring conventional farms and compared. They found no statistically significant differences in the concentration of trace elements in rye, carrots, or potatoes. Conventionally grown wheat had significantly higher cadmium levels in one case and significantly lower levels in another case. Overall, they conclude that organic farming does not necessarily result in reduced levels of cadmium.

Wiebel et al. (1999) assessed fruit quality in Golden Delicious apples from five organic farms and five farms using integrated production methods. They found that in terms of taste, firmness, dietary fibre and phenolic compound contents, fruits from organic farms outperformed the others.

Hogstad et al. (1997) examined sensory quality and chemical composition of carrots from designed trials and from organic and conventional farms. The data were analysed using principal components and partial least squares regression to identify the main factors responsible for variation in quality. One of the most important factors was fertiliser application. Carrots grown with no fertiliser, low levels of mineral fertiliser or with organic fertiliser, had more total sugars, stronger flavour but less crispness, protein and carotene than carrots grown with high levels of mineral fertiliser. Other factors affected perceived carrot quality included precipitation, temperature in June and growth system.

Vitamins were assayed in wheat and barley grown on organic and conventional farms near Prague (Velisek at al., 1995). The water-soluble vitamins thiamin and riboflavin contents were lower from organic farms than from conventional samples. Lipid soluble vitamins were unaffected. The authors explained this difference by reference to the location of the vitamins: the lipid soluble ones are found in the embryo which is less likely to be affected by nutrient imbalances.

In terms of method, food quality research is considered to be very difficult. The overall methodological challenge of matching paired sets of organic and conventional units is vastly more difficult for food comparisons as a high number of extra variables must be accounted for (e.g., time since harvest, climatic conditions at harvest etc...).

2.12 Conclusion

The substantive results show definite differences in the comparison of organic and conventional farms on many variables. The two main topics can be seen: the biological or environmental (including the soil, biological and animal sections of this chapter) and the economic and social (including the yields, economic and social sections). For the environmental and biological research the results are by no means univocal and in some case there is wide variability among both conventional and organic farms. The presence of this variability suggests that management could potentially be improved and this would affect future comparisons of performance. It also indicates that there is potential for future research to improve the effectiveness of organic techniques. The economic and social research shows greater consistency in its findings. The economic analyses generally show that while yields decline profits increase under organic production and the social research finds significant differences between organic and conventional producers.

The research reviewed in this chapter has been diverse in terms of location, methods, and rigour. There has been a large quantity of research in Europe and North America and some in Australia. A wide variety of methods has been used ranging from studies of a single farm or some farms in conversion to other studies using either small or large samples. Differing levels of rigour are used so that most of the research uses comparisons of organic to conventional farming and the most rigorous uses paired comparisons. It appears that research costs limit sample size so that use of detailed and expensive techniques means that the required resources are expended on a small number of farms.

Chapter 3
Discussion and Conclusion

3.1 Introduction

The purpose of this review is not to provide a comprehensive guide to all research in the topic of farm conversion. While there are some direct conclusions that can be drawn from the literature review in relation to specific aspects of organic production, this chapter will not review those findings directly. Rather, this chapter will outline *how* a study of organic conversion might be undertaken in New Zealand.

The first, and perhaps most important, observation is the degree of variability in the results of all these studies. While there are broad trends in the data which generally are positive for organic production, there are significant variations between:

- Country.
- Farm type (dairy, cropping etc...).
- Intensive or extensive systems within farm types.

This variability in the results strongly indicates that the development of organic production in New Zealand must not be premised entirely on conclusions drawn from studies conducted overseas. While there are some areas of biological research which are clearly universal, other areas like economics are potentially variable. Given the reported paucity of studies of organic conversion, and organic/conventional comparisons in New Zealand (see BDFGA, 2001), this review provides evidence of a clear need to undertake this style of research in New Zealand conditions across a range of sectors.

A second important observation is the value of multi-faceted studies. The complexity of the results shown above, and the interrelationships between some of the factors, suggests that single-factor studies of organic farms are of limited value. It might even be possible that the observable variance in research results might be more easily accounted for if multi-dimensional research was undertaken in more cases. This observation mirrors the conclusions of the BDFGA (2001) review of wider research into organic production.

3.2 Research Designs Used to Study Conversion

There are two basic ways conversion has been studied. The first uses data from organic farms only and the second uses data from both organic farms and conventional farms. The first approach can go on to make comparisons to conventional farming, but does not always do this while the second builds in a direct comparison of organic farms with conventional farms. There are also two approaches to sample size: either small numbers are used, ranging from the single case to about ten cases, or large samples are used and data are derived from broad-scale data collection. The different combinations of these approaches means that there are four main types of study as described below.

- Organic farms only

In this design there is no comparison between organic and non-organic farms. Data from organic farms only are considered. Often such studies are of a highly complex and in-depth character with one case being studied or perhaps several cases, but usually only less than ten. The most successful design in this category is when farms are studied longitudinally through the conversion process with comparisons being made between the same farm in its conventional state and later results under organic management. Such longitudinal approaches can have heavy resource implications. They do manage to eliminate some issues of matching, as the exact same farm, farm environment and farm operator are compared between conventional and organic management. As a point of comparison, however, the longitudinal element of such studies has problems. In particular, are the changing effects on properties under conversion the result of on-farm change, or are there unrecognised external factors which cause change? An example for New Zealand producers would be a sudden shift in exchange rates, or a drought, which might dramatically increase or decrease profitability during the conversion process and might be mistakenly attributed to on-farm factors.

- Organic farms only are studied directly but there is comparison to conventional farms.

In this design there are comparisons to alternatives but the primary data gathered are from organic farms and the comparison uses data available from other sources. The sample sizes can be larger because resources are focused only on the organic farms. This style of study utilises the most beneficial methodological aspects of the previous category, but adds in some comparison to conventional farms to act as a point of reference to gauge external factors influencing farm performance. This design is an improvement on the previous one, but still has limitations, especially if conventional data are not longitudinally available, or prevailing data sets restrict the range of variables to be studied thereby restricting the complexity of the organic/conventional comparison.

- Unpaired comparison of organic and conventional farms.

In this design organic and conventional farms are overtly studied. Two samples are taken, data are gathered and comparisons are made. However, the farms are not carefully paired, so it is possible that observed differences are due to farm differences not differences in farming style or organic management. This group of studies highlight the need to have very careful matching of organic and conventional units.

- Paired comparisons of organic farms and conventional farms.

In this design the farms are paired so that their characteristics are matched on as many variables as possible so that the remaining difference between farms is the style or system of farming. (In many cases the matched conventional farms are neighbours of the selected organic farms.) This is the preferred method of examining organic farming, however, pairing alone does not resolve all methodological problems. Even with the most rigorous pairing, there are some aspects of farm production that cannot be paired accurately. Some aspects, in fact, are better studied using the first style of longitudinal analysis outlined above. Further, many paired farm studies engage in comparison of established organic farms in their 'mature' stage, and thus the longitudinal data from the conversion process is not available.

Our conclusion is that a combination of the strengths of the first and fourth styles – organic longitudinal, and organic/conventional paired comparison – can provide the most robust and comprehensive methodology. The following section outlines a research design that can utilise the strengths of both these styles.

3.3 Outline of a Robust Research Design to Study the Effects of Farm Conversion in New Zealand

The intention of this suggested research design is to evaluate both established and newly converting organic growers against the performance of other systems like IPM or conventional production. It is critically important that this evaluation be integrated across all major facets of farm production in order to fully comprehend the effects of farm conversion. Evaluation must include biological, environmental, production, yields, economic, social and health aspects of production. The following design prioritises the integrated evaluation of all of these facets of farm production.

The main objectives of the research must be to:

- Document all the principal dimensions of the transition of farms in conversion from conventional farming to organic farming.
- Compare yield and economic performance of the different farm systems (organic, IPM, conventional).
- Monitor (and test farm-level monitoring procedures) outcomes of farm systems change at all levels e.g., social, technical, economic, environmental, health.
- Utilise both a longitudinal and comparative structure to data gathering.

This can be achieved by:

- Constructing multiple panels of monitor farms in key industry sectors.
- Using panels comprising three cohorts of pre-conversion, fully organic and conventional producers (12 farms per cohort, total panel of 36 farms per sector).
- Deploying Before-After-Control-Intervention (BACI) statistical analysis over a period of six years.

This size of cohort is small enough to enable intensive investigation of multiple factors on each farm. It is large enough, however, to enable BACI statistical analysis to take place.

Methods of data analysis can be designed around the Before-After-Control-Intervention (BACI) statistical design which tracks changes in matched production systems over time. In the absence of random allocation of farms to the treatments and the control, it is necessary to match farms in each of these groups. Relevant variables for matching include soil type, size, location and socio-economic composition. With careful attention to matching, the recorded differences in outcomes over time can be attributed to the style of farming. BACI analysis makes sample size requirements modest: sizes of from 5-10 farms are adequate to allow for the identification of relevant statistically significant results. Because the design operates over time it is possible for some farmers to leave the study, so a slightly larger sample (12) is needed. Within a BACI design, T tests and a modified Chi square test are suitable for testing if the measured differences are statistically significant. The hypothesis to be tested is that there are no differences across farm types over time, that is, any recorded changes are similar across farm types.

An advantage of the BACI design is that it allows for detailed on-farm measurements to be made since the costs of research are spread over a modest number of cases. In survey research with larger samples one has to rely on reports from farmers rather than first-hand observations. This strength is particularly relevant for many of the environmental variables of interest such as soil nutrient effects or effects on fungi or arthropods. It remains the case that good farm level data can be usefully compared to available data from other sources such as surveys.

At a minimum, two cohorts are required for each sector:

- Pre-conversion farms intending to convert to organic production in the following year.
- Conventional or IPM producers.

At the heart of the BACI design is the need to start all farms in these two cohorts from the same position – conventional production. The organic cohort commences as conventional and then shifts as production systems are changed during conversion. BACI analysis can then identify the magnitude and significance of changes between the two cohorts. The rationale is similar to that of the longitudinal approach discussed above, but instead of comparing organic performance to one fixed point of conventional production (the same farm pre-conversion), the point of comparison with conventional can happen in the same temporal timeframe as the converting organic property. This then eliminates the distorting influence of externalities which can undermine the purely longitudinal design outlined above.

In addition, since we want to have some early data to indicate potential differences between conventional farms and organic farms, a third cohort of mature organic producers can be matched to the first two cohorts. The advantage of this is that it allows the converting organic farms to be simultaneously measured against both the conventional and the mature organic cohorts.

In summary, the BACI design allows for dynamic and static analyses. First, comparing conventional with organic farms allows for a static comparison of established farming systems with good evidence for the case, where measured differences are found, that farming system has causal effects. Much of the international literature uses this design. Second, and more convincingly, dynamic analysis of change from the matched base of similar conventional and converting farms allows very rigorous conclusions that measured differences can be attributed to the farming system. Some of the international research is dynamic in that one or a small number of farms are studied over time but usually it is just organic farms that are studied. The BACI design allows for the combination of static and dynamic analysis and has not been applied in any of the research reported here. As such the development of the BACI design and its application to farm conversion in New Zealand will be unprecedented and unique.

3.4 Topics or Variables to be Included in the Analysis

The ideal research design is one that allows for any key variable of interest to be included in the study. The BACI design, by focussing on the farm-level effects of conversion and using a modest number of farms in the sample, allows for this important requirement to be met. In order to understand the effects of conversion in New Zealand it is important to be comprehensive in the coverage of variables. Thus, the aim is to create an integrated body of data for each sector studied. This requires attention to many different facets of farm production, including the following topics.

- Environmental Outcomes. The environmental impact of farm systems change provides a major portion of this analysis. Topics of interest include soil, biodiversity, greenhouse gas emissions (GHG), carbon sequestration, water and energy outcomes.

- Economic. Utilising the relatively simple mechanism of farm financial accounts, coupled with a more complex input/output matrix to provide a broader accounting of farm activity.

- Social (on-farm and community). Investigating the transformation of household composition, labour use on farms, off-farm work activities, demographic shifts in the cohorts, cultural and gender dynamics, grower attitudes/values/intentions and processes of decision-making on farms. A further dimension to social analysis is impacts on local labour markets and communities caused by farm change.

- Extension. All these dimensions are currently subject to the development of auditing and monitoring procedures. It is important not to reinvent these processes, but to deploy them in a way that enables their utility to be evaluated – and the resultant data to be incorporated into BACI analysis. Further, the process of the study should seek to integrate grower groups into the monitoring process to enable future self-monitoring to take place.

- Health. The health outcomes of farm systems change is relevant to the health status of workers and family on-farm, as well as the wider outcomes on community health.

For each of the BACI cohorts, a standardised body of monitoring devices should be deployed over a period of six years. While there are numerous ongoing monitoring activities that take place in New Zealand, this would be the first to integrate across economic, production, social and environmental activities.

3.5 Some Methodological Considerations

While the BACI design has never been attempted before, there are some predictable elements to the operationalisation of the design which would need careful consideration or management.

The most obvious concern for any cohort-based longitudinal study is attrition. It is inevitable that some growers will drop out of the study, sell their farms, or no longer continue farming. Consequently, the size of the original cohort must be generous, while being as restrained as is possible to reduce costs. The suggested size is 12, as BACI analysis can operate with cohorts of 5-10, and an original number of 12 gives ample room for attrition.

Selection of eligible participants is also a major challenge. For BACI analysis to work, 12 growers must be recruited in the same farm sector, all of whom are intending to register for organic conversion in the subsequent year. To achieve recruitment of such a group, a high level of cooperation with farm organisations and organic grower groups would be required. This requirement, however, means that only relatively large organic sectors, with increasing numbers of growers, can be studied.

Previous studies show that choosing the matched conventional farm from one of the organic farm's neighbours appears to be a good way of matching. But one observed difficulty is cohort swapping. Put simply, how do we stop the matched conventional farmers from becoming organic or changing their conventional practices towards organic practices? The opposite applies, with organic conversion properties returning to conventional production. If the two tendencies happen at a similar rate, then BACI analysis can still be used, but prior comparative studies suggest a problem with too many conventional farmers wanting to commence conversion to organic production mid-study. This problem may be resolved by careful recruiting of farmers committed to their particular style of management. Committed farmers are more likely to stay with their management system for a number of years. There is still considerable interest among New Zealand farmers in conventional farming, so sufficient numbers could be obtained, and they will have an interest in supporting their approach to farming rather than the alternative.

Much of the research reviewed here uses the intermediate category of Integrated Pest Management, low input or Integrated Crop Management as an intermediate position between organic and conventional. Adding an entire third cohort of IPM producers would add considerable costs to the BACI design. However, in New Zealand conditions this may not apply as those sectors that have broadly adopted IPM, like kiwifruit or pip fruit, have essentially moved conventional production into IPM-based production. The research design decision would therefore be whether one of the cohorts would be *either* conventional or IPM.

One problem that might be relevant is the Hawthorn Effect: the presence of researchers stimulates atypical levels of achievement. In a study that compares organic and conventional methods, there is perhaps an expectation that the organic farms are important since the main purpose is to see if conversion has any effects. The organic farmers may believe that they are under scrutiny and may believe that they have an important role to play in showing the way forward so they behave accordingly. That is, it may be that the Hawthorn Effect operates. However, conventional farmers are also under scrutiny and they may believe that they have just as important a role in seeing that conventional farming is seen positively so they work hard to support it. Further, one way to address this potential problem is to provide guidance on the protocols for farming by either style. It is unlikely that each farmer will be farming 'alone' and be using their own discretion on exactly how to farm. They will be guided by standards agreed at the beginning of the experiment and by ongoing monitoring and supports provided by the research team which will include experts in both conventional and organic techniques.

A related problem stems from the important distinction between farm management or farming ability and production system. That is, it is important to ensure that farming ability in each group is average. It may be important to ensure that in the sample of 12 cases the level of farming ability is averaged out for each cohort. This problem can be minimised by the provision of expert guidance.

3.6 Sectors to be Studied

It is proposed that four important primary production sectors should be evaluated. An important criterion is that the sectors must have a sizeable organic sector (certainly enough to provide 12 'mature' organic farms). It must also be experiencing high levels of new grower interest to enable the cohort of converting growers to be established. With this in mind, candidate sectors in New Zealand include: dairy, pip fruit, kiwifruit, field crops and pastoral farming.

Dairy is the strongest possible candidate in New Zealand at the present time. It has enough established growers to provide the mature cohort, and it is currently experiencing high levels of interest from conventional growers interested in organic production.

Pip fruit is another strong candidate sector with sufficient mature organic growers and numbers of growers converting.

Pastoral farming is emerging as a candidate sector. There are a number of mature organic growers. Levels of grower interest in organics is increasing, but it is not guaranteed that a full cohort could be formed in the immediate future.

Kiwifruit is now past its best as a strong candidate for BACI analysis. Levels of grower conversion to organic have tailed off in the short term. Mainstream production has now fully moved from conventional to IPM.

Field crops is another sector in which levels of grower conversion might not be sufficient to enable 12 to be identified wishing to convert in any single year.

For all these sectors, a positive application of the Hawthorn Effect might assist the recruitment of growers as potential converts to organics. The strong levels of monitoring inherent in this design, and access to any data by growers involved in the study, might make growers feel more secure about the move to organics. If widely publicised activities involving grower groups took place, it may be possible to 'flush out' potential interested growers at a higher level than might be expected.

3.7 Supplementary Outcomes

There are a number of outcomes over and above the causal analysis available from the application of this research design:

- Deployment of economic data through trade modelling to enable more accurate prediction of economic benefits for New Zealand from adopting different strategic options.
- Linkage and co-ordination across different sectors and research activities to enable an integrated evaluation of multiple processes – economic, social, environmental, health – which interact in complex farm systems like organics.
- Robust evaluation of the utility of on-farm monitoring and extension tools.
- Strong linkages between researchers and industry-groups, with the intention that industry groups become up-skilled to conduct ongoing self-evaluation.

3.8 Conclusion

This review has examined how New Zealand might undertake a study of the consequences of organic conversion. The many studies reviewed here clearly indicate that the many factors involved in organic conversion have variable outcomes in different countries, industry sectors and styles of production. Consequently, New Zealand requires a specific body of research to understand the consequences of organic conversion in our conditions. Such a study has not yet taken place. Preliminary work has suggested that there are a number of positive outcomes to organic conversion, but there is no broad body of data available in New Zealand conditions to substantiate and elaborate on these tentative early findings.

A second important observation is the value of multi-faceted studies. The complexity of the results reviewed here, and the interrelationships between some of the factors, suggests that single-factor studies of organic farms are of only limited value. It might even be possible that the observable variance in research results might be more easily accounted for if multi-dimensional research was undertaken in more cases. This observation mirrors the conclusions of the BDFGA (2001) review of wider research into organic production.

Among the different styles of research into the conversion of organic properties and the relative performance of organic and conventional properties, we identify four types:

- Organic farms only – in which single or small groups of organic farms are examined or followed through the conversion process.

- Organic farms, with limited comparison to conventional – where primary focus is on organic farms, with some limited comparison to existing data on conventional farms.

- Unpaired organic and conventional – where both groups are directly examined, with no attempt to pair the farms.

- Paired organic and conventional – where attempts are made to reduce unwanted variance between the farm types through pairing farms.

Our analysis suggests that the most merit lies with the first and fourth approach, but that each has shortcomings on its own. Consequently, we have proposed a research design that utilises the Before-After-Control-Intervention (BACI) design to utilise the strengths of both longitudinal and paired comparison.

The proposed design requires three cohorts of 12 farms per industry sector. The three cohorts are: conventional farms, 'mature' organic farms, and conventional farms that are about to enter organic conversion.

Over a period of six years, these three cohorts would be observed using intensive on-farm sampling and observation, the deployment of monitoring systems, and the training of farmers in the use of self-monitoring systems.

While there is a great deal of methodological virtue in the BACI design, there are some practical drawbacks in undertaking such research. Primarily, a BACI design requires specific numbers of growers to attempt organic conversion in the same year. There are only a few sectors that could fulfil this with any certainty in New Zealand, however, it is anticipated that dairy, pip fruit and pastoral sectors would be likely candidates.

The other constraint is the resource-intensive nature of a six-year study.

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