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Review

A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture

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Abstract

There is currently considerable discussion about the merits of particular forms of agriculture. The discussion has been generated by excess food production in the EC, continuing public disquiet over the use of chemicals in food production and political agitation. Much of the debate concerns the merits or otherwise of organic agriculture which is often seen by the public as producing food free of chemicals and being more environmentally friendly. This article examines these notions critically dealing with each of the individual claims frequently made for organic agriculture. The article concludes that in the UK, at least, when problems with agriculture emerge they usually hinge around poor management not mode of agriculture. In environmental terms no-till farming currently seems to be better than others. The benefits of holistic thinking by farmers are indicated.
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Keywords: Organic farming; Soil use; No-till; Pesticides; Farm environment

Contents

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1. Introduction

Organic agriculture has developed rapidly in the European Community. An excess of food production and an increase of wealth enables different but less efficient forms of agriculture to survive. However organic agriculture is different to other current forms such as conventional agriculture or integrated farm management (IFM) because it has a well-established ideological base and groups of often vociferous supporters who are usually not farmers. This situation has led to claims about organic agriculture which is the subject of this critical article. The three primary points are; (1) that organic food is healthier because it does not contain synthetic pesticide traces, (2) that the soil structure on organic farms is much better leading to less pollution from nitrate and is healthier for the crop plant, and (3) that environmentally organic is better than the other forms and is chemical free. Each of these claims is examined in turn and in some detail.

Organic farming owes its origins in part to the development of biodynamic farming by Steiner (1958). However this form of farming with its belief in cosmic forces has no place in any scientific discussion and is considered occult in character (Kirchmann, 1994). Organic agriculture, at least in the UK, built upon aspects of Steiner in terms of self-sufficiency of small farms, a belief in the health of soil producing healthy plants (and healthy people) and a rejection like Steiner of the use of any chemicals (Balfour, 1948). The general history of the organic debate has been described in detail by DeGregori (2004). The notion of self-sufficiency was formulated at a time when it was thought agricultural resources were running out. However there is sufficient phosphate rock to last 1000 years (Simon, 1996) and the Haber Bosch method converting gaseous nitrogen to ammonia can provide for unlimited fertiliser N (Smil, 2000a). The only resource that might constrain agriculture could be available farmland, but organic agriculture is less efficient in its use of land. Instead of lack of resources, it is now resource over-use, the global impact of their use along with global warming and a growing population that represent major concerns (Trewavas, 2003). Where appropriate these problems are referred to. A common claim, that agriculture has failed, is simply contradicted by the abundance of produce in present day supermarkets.

In a democratic society those who wish to farm organically (or biodynamically) or to eat organic food have a perfect right to do so. It would be helpful if the organic ideological community would recognise that right in reverse for others to farm in the way they wish. In a pluralist society all have rights. GM crops would be the simplest way to introduce the enormous environmental benefits of no-till agriculture, but organic regulations that insist that organic food must have zero GM presence are in turn an attempt to impose organic regulations on everyone else and may limit the introduction of widespread no-till to UK agriculture. As in all industrial processes, certain tolerances in production are accepted and these should be instituted.

1.1. Comparisons between different kinds of agriculture to examine strengths and weaknesses

Throughout this article comparison is made between different kinds of agriculture. Organic agriculture is defined by its regulations. Integrated Farm Management is defined by the LEAFUK (Linking environment and Farming) audit, the main IFM group in the UK. LEAF specifies exacting standards of landscape, hedgerow maintenance, large field margins, quality soils and provides good animal welfare (Drummond, 2000), all supposedly features only of organic farms in the public mind. But what exactly is conventional farming other than simply not being organic? And when comparisons are made, what evidence is there that the conventional farm is representative of this weakly characterised farming procedure in any way. Unless evidence is provided on this point and perhaps the average conventional and average organic farm stipulated, published comparisons should be treated critically. Use of best practice conventional and organic farms (if that can also be defined) might improve the quality of comparison. The only specific features that really distinguish organic from all other forms of farming are a rejection of soluble minerals as fertiliser and synthetic pesticides in favour of natural ones. Any conventional farmer can choose to incorporate the supposedly unique organic environmental features into their farm and many clearly do; incorporation of manure to save on fertiliser, for example.

The variety of conventional farming procedures and farms causes difficulty in attempting comparisons. Not only do UK farms vary in climatic experience, ranging over nearly a 1000 miles of latitude, varying in rainfall, wind, average temperatures, exposure, slope, soil types and quality, mixed and arable, hedgerow structure, weed and pest problems but they also vary in managerial quality and attitude, level of farmer education, farmer understanding and finally wealth. Although attempts are made to supposedly match soil quality when comparing conventional and organic farms, recent investigations using GPS controlled metre-by-metre surveys (precision farming) have indicated how variable is both the organic and mineral content of supposedly uniform fields (Smil, 2000a). Comparisons that are made between conventional and organic farms commonly rely on farms nearby to each other to minimise (but not to eliminate) environmental variation. The presence (or absence) of trees and hedgerows which modify environmental impact are usually ignored. But managerial quality itself invariably fails to be investigated or estimated even though it is of obvious importance.

What exactly is farm managerial quality? A farm is a densely interlinked structure forming a system or network that is ultimately controlled by the farmer and his degree of understanding of its behaviour (Fig. 1).

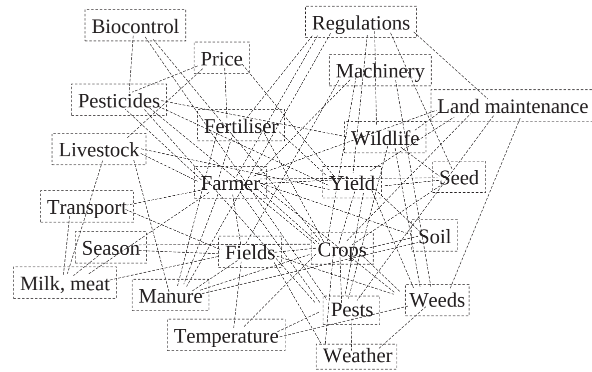

Fig. 1. A simplified view of a farm as a system. A system can be regarded as a network composed of inter-linked elements that influence each other. A boundary can be drawn around the system to simplify understanding. To demonstrate linkages within the system it is sufficient to indicate that modification of one component modifies others in turn. In the figure these linkages are drawn as dotted lines. A proper systems structure would attempt to estimate the strength of linkages although bearing in mind that the strength will vary with circumstance (for example, manure will affect crop yield less if minerals have previously been added). But in a farm all system constituents are ultimately linked to the farmer and his ability to adaptively manage. Successful farmers appreciate the systems nature of their farm and act accordingly although they may do this intuitively and with wisdom gained from experience. The context around the boundary is composed of weather, crop price, price volatility and other financial arrangements that influence the overall farm system structure.

In simpler terms we can recognise standards of farming excellence much as is commonly recognised in science, education and medicine. It is not difficult to recognise low farm standards; rusting machinery, half covered in grass; un-maintained or no hedges; holes in barn roofs, un-repaired gates; a pool of excrement outside the cowshed and so on. Furthermore, poor management and lack of biological understanding results in excessive use of costly pesticides thus wasting money; failure to use manure on a mixed farm to offset fertiliser costs wastes money, as well as failing to take advantage to maintain soil quality; poor treatment of animals leads to lower yields; failure to maintain hedgerows or large field margins limits pest predator numbers requiring more pesticide and so on. When farms fail the commonest reason is apparently poor financial, that is managerial, control in the face of a variable market (Hansen and Jones, 1996). The IFM and organic benefits of wide margins, soil quality, landscape and good animal welfare help to limit the year-to-year variation in income, the major enemy of sustainable farm practice.

Perhaps the crucial feature here is that comparison of well-managed and poorly managed conventional farms will result in all the same landscape and animal welfare differences as those supposedly separating organic from conventional. The answer to this difficulty in scientific comparison of organic and conventional farming is simply to emphasise comparisons made on the same farm, matched fields and using the same farmer to avoid managerial variation in standard.

Most organic farms are supposed to remain small and self-sufficient whereas conventional farms are increasing in size the result of economic pressures. It will be increasingly difficult to make valid comparisons between the two. Farms, of necessity, do interact with each other and other facets of the commercial and food production community, constructing a complicated network. From what we now understand about network stability, small farms interacting minimally as a result of a policy of self-sufficiency do not generate stable networks, which instead require a limited number of hubs with very numerous interactive links (such as large conventional farms) coupled to many smaller constituents with fewer links (Barabasi, 2002). Organic regulations if expressed country-wide run directly counter to efforts to stabilise agricultural production. One possible structure that might be more stable is a diverse multi-hub network but this would see organic agriculture as merely a niche activity, not a primary form of agriculture.

Poor management survives because of subsidies, the curse of quality farming practice. Will organic action plans upgrade managerial standards then? Organic farming is recognised as higher risk (Leake, 1997) because of crop failure and market variation. Thus only the best, most competent farmers are likely to try organic farming and probably only on a few of their fields. Therefore competent management will merely be transferred from one kind of farming to another with no overall improvement.

As stated earlier, the simplest comparisons between organic and conventional agriculture is to use the same farm run by a farmer of excellent managerial quality. There are several established UK examples in the 10 year experiment at Boarded Barns, Ongar, Essex (Boarded Barns, 2000; Higginbotham et al., 2000) and the 7-year experiment at Cooperative Wholesale Society (CWS) farms at Stoughton, (Leake, 1997, 1999a, b, 2000a, b). Long-term experiments at Broadbalk, Woburn and Saxmundham may also be informative (Johnston, 1991; Rasmussen et al., 1998; Russell and Voelcke, 1936). There have been comparisons in other countries (Rasmussen et al., 1998) but climate and soil differences make these less useful in an article primarily directed to UK farming.

It takes decades to assess the effects of changes in agricultural practice and disadvantages of organic farming could take this length of time to appear. Many countries in the world practice organic farming now; but not by choice, but from poverty. When the UK was recognisably organic in the past (1900 for example), life expectancy was much lower, yields were lower, a substantial segment of the UK population were malnourished and/or ate a poor diet. Food in real terms was much more expensive. In 1900, for example, 60% of potential recruits were rejected for army service in the Boer war because of poor stature and weight resulting from poor diet (Drummond and Wilbraham, 1940; Orr, 1936). Price and the knock on effects on consumption are major concerns with organic food and one which should not be ignored. Food abundance reduces price.

2. Pesticide traces in conventionally produced food causes cancer

2.1. Background

Chemophobia, the unreasonable fear of chemicals, is a common public reaction to scientific or media reports suggesting that exposure to various environmental contaminants may pose a threat to health (Safe, 1995). The spectre of cancer birth defects and irreversible effects invariably scares people and various groups that campaign on environmental issues find the anxiety raised a useful source of political issue. Virtually all chemicals can be shown to be dangerous at high doses and this includes the thousands of natural chemicals that are consumed every day in food but most particularly in fruit and vegetables.

The assessment of chemical safety normally requires determination of the maximum tolerated dose (MTD) in rodents. Doses slightly lower than this figure are used to extrapolate linearly to a concentration at which observed effects would be limited to one in a million of the population and a ''safe'' exposure for the public set at figures 100-fold lower than this. Thus the safe level is frequently 10^{-5}–10^{-6} the MTD and on theoretical grounds it is very unlikely that the same cellular receptor (binding) sites could be occupied and the same effect induced, varying only in degree. Most cellular binding sites go from null saturation to full saturation over a 30–50-fold change in dose, not one million. The effects at high dose are therefore a priori expected to be qualitatively different from low dose and the effects of toxicity or cancer of little consequence to public exposure (Ames and Gold, 2000). Ames and Gold (1999) indicate that the carcinogenic effects of many chemicals at MTD are really the result of induction of cell division which normally occurs only at high dose.

The public attitude towards synthetic pesticides derives from the views of Rachel Carson (1962). Unfortunately anecdotal evidence forms much of the basis of Carson's book and a number of simple errors have been identified (Van Embden and Peakall, 1996). While Carson's book helped alert to the impact of agricultural techniques at the time on the environment, her primary misunderstanding resulted from the claim that ''for the first time'' the human population was exposed to chemicals (pesticides) from birth to death. Plants synthesise an estimated 10,000 chemicals whose function is to kill or deter insect pests and occasionally larger herbivores. These natural pesticides are found in all fruit and vegetables; when tested at MTD they prove to be equally as damaging as synthetic pesticides (Ames and Gold, 1999, 2000). Furthermore the daily consumption of natural pesticides or carcinogens outweighs the traces of synthetic pesticides consumed by the public by many thousands to one. Mankind has always been exposed to "dangerous" chemicals and since many current crops have only recently been used as food and are also the result of extensive plant breeding, the kinds of natural chemical to which we are now exposed is too recent to allow for biological evolution to have ensured safe consumption (Ames and Gold, 1999). Solanine, chaconine, cucurbitacin, psoralen and genestein in potato, cucurbits, celery and soy have all been shown to have physiological effects if slightly elevated in food (Trewavas and Stewart, 2003).

Carson (1962) alerted in her book to the potential effects of DDT accumulation through food chains, to observed eggshell thinning and thus brood failure of predatory birds. Attempts to repeat these observations in the laboratory failed (Wildavsky, 1995). However because organochlorines like DDT are environmentally stable, bans on its use were instituted in the early 70's. In western countries DDT was replaced by effective but far less stable pesticides. But pressure on developing countries to do the same led to enormous increases in malaria, a disease that particularly kills young children (Attaran and Maharaj, 2000; Simon, 1996). In developing countries, cheap DDT also killed many crop and other human disease insect vectors and lowered food prices that benefited the poorest most. Recent evidence has revealed that organochlorines are formed in substantial amounts (mg/kg) in decaying plant materials such as crop roots in soil (Myeni, 2002). Because organochlorines are fat soluble, they will be found in all plant food materials and mankind has therefore been exposed to these stable chemicals probably throughout evolutionary history and so far as is known without effect. In fact any natural pesticide can bio-concentrate like DDT if it is fat soluble. Potato contains the fat soluble neurotoxins, solanine and chaconine, and high doses of these have been shown to cause birth defects (Ames and Gold, 1999).

However chemophobia is the commonest reason for the public to buy organic food on the assumption that such food is free of synthetic pesticides. Organic food contains synthetic pesticide traces although understandably the amounts are lower than in conventional produce (Baker et al., 2002).

Life expectancy continues to increase unabated (Oeppen and Vaupel, 2002) and figures specific for the UK are to be found in Lomborg (2001). Centenarians are now ten times more common in the UK than they were 50 years ago. There has been no obvious effect of the introduction of pesticides and use through 50 years on life expectancy or on general public health (Coggon and Inskip, 1994).

2.2. Agricultural exposure to pesticides and cancer

Specific synthetic compounds have been linked to cancer as a result of occasional high level of occupational exposure (such as benzene on Turkish shoe makers) or accidents such as Bhopal. In order to link together public exposure and cancer there must be correlations between the level of exposure and the magnitude of the response, consistent results from a number of different studies, and biological plausibility based on studies in laboratory animals. If there is such a relationship, it can be hypothesised that it should be most readily apparent between cancer rates and those most exposed to pesticides.

Since farmers, foresters, pesticide users and manufacturers are by occupation more likely to be exposed to higher pesticide hazards than the general public, many published studies have investigated cancer rates in these groups usually through cohort investigations using matched controls from the public particularly in age and social status (Blair and Zahm, 1991; Blair et al., 1993; Dich et al., 1997; Faustini et al., 1993; Maroni and Fait, 1993; Wiklund and Dich, 1995. Of 12 separate investigations on farmers involving in total about 300,000 people, 11 found that farmers had overall cancer rates very substantially lower than the general public. Slightly smaller numbers of investigations on pesticide users and foresters revealed a similar (8 out of 11) trend whilst only with manufacturers were cancer rates similar to those of the members of the public. The reasons why farming is so healthy are not known but these data indicate not only a null result for the hypothesis relating pesticide exposure to cancer but a consistent result for the alternative, that pesticide exposure may protect against cancer. These results are also consistent with a hormetic effect of low pesticide doses (see later). Farmers do have higher rates of the less common lymphoma but evidence indicates that lymphoma is unrelated to pesticide exposure (Cantor et al., 2003). Higher exposure to animal disease viruses or fungal disease may be a more plausible hazard.

Cancer death rates in the UK are in decline particularly when lung cancer induced by smoking is removed from the 50 years of detailed age-related statistics published by the epidemiologists Coggon and Inskip (1994). They conclude "there is no evidence that pesticides have had a major impact on overall rates of cancer". Cancer rates increase over 100-fold between the ages of 20–70. Thus increased numbers of cancer cases accompany an increasingly healthy population dominated by elderly people. Only when cancer rates (cases/numbers of people) are expressed for each defined age group as shown in Coggon and Inskip (1994) for every 5 years of age are genuine trends detectable.

Although cancer death or cancer incidence, could be examined, it was common 50 years ago for pathologists to report that coronary fatalities also had advanced cancer. As fatalities diminish from heart failure more die from cancer. The estimates of human recovery from cancer do not seem to be above 5–10% of diagnosed cancers, so although incidence might be considered a more useful criterion of environmentally damaging materials, death rates may be considered a more valid, easily diagnosed measurement (Coggon and Inskip, 1994). It is among the young and middle aged that anything untoward concerning illness first appears (Doll, 1992) and these two groups show the greatest declines in cancer rates over the last 50 years. Some cancers such as breast cancer are increasing but the factors that conspire such as lifetime oestrogen exposure and most significantly obesity (Callee et al., 2002) are the probable major risks (Safe, 1998, 2000). The stomach is the most likely tissue substantially exposed to ingested pesticides but stomach cancer rates have declined by about 60% in the last 50 years (Department of Health, 1998).

The Government's Committee on Carcinogenicity (COC, 1999) after examining the evidence in detail concluded that breast cancer rates are completely unrelated to organochlorine exposure. Of the 43 separate investigations that I have found on this issue (lists are to be found in Gammon et al., 2002, Attaran and Maharaj, 2000, and see Safe, 1995, 1998, 2000) at least 80% find no relationship at all and these include some very large surveys involving hundreds of thousands of women. Those that find some slight relationship are usually very limited in scope and fail on the grounds of consistency (Attaran and Maharaj, 2000), a conclusion supported by Smith (2000) discussing in detail the toxicity of DDT. Perhaps more intriguing with the large investigations involving 50–150 thousand women, cancerous tissue has slightly less DDT, DDE the main metabolite and PCB's although the difference is within the standard error. The issue of DDT traces is primarily concern about bio-accumulation rather than known toxicity.

2.3. Possible xeno-oestrogenic effects of pesticides

During the last decade there has been debate about a potential new threat to human health, exposure to chemicals potentially with endocrinologic activity; the so-called "endocrine disrupter" hypothesis. However measurements place this argument in perspective. The major dietary source of oestrogen-mimicking molecules are flavanoids and isoflavones in fruit and vegetables (Nilsson, 2000). The daily consumption, about 1–2 g/day, represents oestrogen equivalents (determined in the neo natal rat) about 3% normal circulating level of oestrogen in the non-menopausal female. The current dietary exposure of dibutylphthalate from plastic would increase circulating oestrogen-mimic content by 0.0006% and from dioxin and organochlorines by 6×10^{-6}%, (Nilsson, 2000; Safe, 1998). In contrast the levels of oestrogen mimics in certain alternative medicines is sufficient to cause physiological changes in treated men (Nilsson, 2000).

Concern over the consumption of soy genestein particularly in vegetarian diets using soy milk for pre-puberty children has been raised. Genestein is an established genotoxin (Snyder and Gillies, 2003) and evidence from human studies suggests potential modifications of thyroid function leading in the long term to goitre (Doerge and Sheehan, 2002).

2.4. A diet high in fruits and vegetables cuts cancer rates in half

Block et al. (1992) summarise some 200 investigations on diet and cancer using cohort studies over the previous 20–30 years. These authors indicate that for virtually all the major cancers, a diet high in fruit and vegetables cuts cancer rates approximately in half. These investigations involved very large numbers of people, only in western countries, and those under investigation consumed conventional produce containing the inevitable pesticide traces. The fact that increased consumption of these supposedly damaging substances in fruit and vegetables actually makes you healthier, contradicts any simple assumptions concerning pesticide traces and cancer.

Furthermore we now know that fruits and vegetables contain an estimated 10,000 secondary products. When tested in exactly the same way as synthetic pesticides, at the MTD, 60% of each were carcinogenic (Ames and Gold, 2000). But a number of these like limonene, perillyl alcohol, quercetin, allyl isothiocyanate, all carcinogenic in high doses are now used to treat cancer but at low doses. (The notorious poison, arsenic, has also been used to treat leukaemia, (Trewavas and Stewart, 2003). These natural pesticides (so-called because they are synthesised by plants to poison insects and herbivores) will also be consumed in greater amounts with diets high in fruit and vegetables. The quantity on average consumed/day of natural pesticides outweighs synthetic pesticide residues by 20,000 to 1 (Ames and Gold, 1999). These results indicate that the tests and assumptions, used to identify synthetic pesticide traces as damaging to humans, lack meaningful interpretation since consumption of natural pesticides does not induce cancer.

2.5. Hormesis indicates the potential value of synthetic chemicals in the diet

Hormesis is the paradoxical effect of toxic chemicals at low concentration (Calabrese and Baldwin, 2001, 2002, 2003a, b; Trewavas and Stewart, 2003). Many toxins at high concentration are likely to have the opposite (and thus probably beneficial) effect at low concentrations. There is an enormous toxicological literature on this subject and Calabrese and Baldwin (2003a, b) refer to hormesis as a revolution in toxicology.

The standard method of assessing toxicity was based on a model of cancer that is now outdated. This model assumed that toxic at high concentration simply meant less toxic at low and that there was no threshold below which effects of pesticides were absent. Consequently no concentration of any toxin could be considered absolutely safe. The theory became known as the linear no-threshold theory (LNT) and was formulated in the 1970s. Developments in our understanding of cancer have shown the basic assumptions (all mechanisms of cancer the same; cancer as a monotonic disease) that under-pinned the model are incorrect.

Instead many chemicals in the low dose region have a dose response curve that is J-shaped, indicating, for example and where relevant, that low toxin consumption actually inverts the physiological effects of high dose (Trewavas and Stewart, 2003). Data collected from 5000 dose response measurements (abstracted from 21,000 papers) indicate that low doses of many supposedly toxic chemicals, metals, pesticides, fungicides, petroleum fractions, radiation and even diluted factory effluent either reduce cancer rates below controls, increase longevity or growth in relevant organisms (Calabrese and Baldwin, 2003b).

There are many familiar examples of hormesis. Aspirin, where one or two tablets/day improve the circulation, but 30 will stop it altogether. Virtually all pharmaceuticals are similar. Fluoride to strengthen bones and teeth but fatal in large doses. Antibiotics and vaccines where a 10-fold higher than recommended dose can kill. Sunshine induces vitamin D formation in small doses, but melanoma in large doses. Radon, a radioactive gas formed in higher amounts in granite houses but those who live in such houses have lower rates of lung cancer (Pollycove and Feinendegen, 2001). Vitamin A is necessary for vision but teratogenic at slightly higher than recommended doses (Kuiper et al., 2001). Insulin is the crime writer's invisible murder weapon at high dose, but necessary to control human blood glucose level at low dose. Drinking water suddenly in very large amounts has been known to kill by upsetting the ion balance.

Hormesis is thought to result from the beneficial effects of mild chemical stress at low concentration potentiating the immune and oxidative defence systems; in turn destroying pre-neoplastic loci. Well-established cases show that low doses of chemicals like cadmium (Waalkes et al., 1988) or dioxins (Kociba et al., 1978) or anthracenes (O'Gara et al., 1965), for example, actually lower cancer rates below control levels. In other words if synthetic pesticide traces are at a level to have any effect at all (and they probably are not), the effect is as likely beneficial as anything. The expected hormetic effect of natural pesticides in fruit and vegetables potentially accounts for their beneficial action in reducing cancer.

2.6. The price of fruit and vegetables determines health

Organic food is more expensive because it uses land less efficiently, as will be seen later. However only 21% of the UK and only 20% of US citizens actually eat the necessary two fruit and three vegetable portions/day recommended by respective governments to provide minimal protection against cancer (as indicated by Block et al., 1992). Those numbers will not be increased by raising the price of produce because it is known that price is a very strong determinant of consumption (Knutson, 1999; Lutz and Smallwood, 1995). Furthermore raising the price will not encourage the cultural change necessary to increase fruit and vegetable consumption. For those on low incomes, if organic food is purchased less will be consumed, with consequences in cancer rates decades later.

2.7. Conclusion on pesticides and cancer

On current views low levels of synthetic pesticide traces could have beneficial effects on health but much more and difficult research is needed to clarify this issue. Because conventional food is also cheaper and increased consumption has improved the health of the UK population, conventional food can be regarded as healthier than organic food. The fact that stomach cancer rates have declined by 60% in western countries since 1950 is ascribed to the fact that conventional fruit and vegetable consumption has doubled during that period. Furthermore the epidemic of allergy disorders including asthma in the UK is increasingly being suggested to result from environments which are too clean. Removing beneficial chemical traces from food that help potentiate and energise the immune system might make matters worse for health. As hunter-gatherers, mechanisms like hormesis would have been essential to enable humans to eat a diversity of food in variable condition but without long-term health damage. We have good defence mechanisms to deal with low doses of chemicals in our diet. Pesticides keep fruit and vegetables cheap thereby encouraging consumption. The primary problem with pesticides is that they do kill insects other than those which are pests and which can be beneficial. The eventual evolution of pesticide resistance constrains their agricultural value. However careful use of pesticides as in IFM can greatly prolong their usability and transfer to these kinds of farming system should be encouraged (Van Embden and Peakall, 1996). A technology that improves natural crop resistance reducing pesticide use, such as GM insect-resistant crops, should be beneficial.

Much of the antagonism against pesticides assumes that mankind is the only organism releasing chemicals into the environment. However as organisms we possess a unique faculty, that of high intelligence; a natural property that can be used for benefit or damage as anything else in nature. Every organism releases chemicals into the environment and the soil. The most obvious are oxygen, methane, nitrous oxide, DNA upon death, urine and other excreted products amongst many thousands. Isoprene emitted in enormous amounts by trees (about 400 Tg/year) modifies local climates (Fuentes et al., 2000). Many plants also release numerous secondary and poisonous products, including allelopathic compounds, into the soil environment, aimed at killing other organisms. The public supposition that synthetic pesticides are dangerous because they kill insects fails to recognise that natural pesticides, that we consume every day in abundance, do exactly the same thing. Fungal and blue green algal toxins are well known. Few of these "natural" chemicals are ever looked for in human beings and it is perhaps time that they were; the public perspective might then change.

2.8. Where organic naturalism ideology leads

A common claim is that intensive agriculture seeks to dominate nature whereas organic agriculture works with nature. It is not very clear what the statement means since no form of farming is natural relying in every case on clearing ground and destroying the natural environment (forest and the associated organisms) that was there before.

However the phrase uses the term "nature", appealing to a common phenomenon described by E.O. Wilson as Biophilia. Human beings recognise the natural world and often feel a strong kinship with it because we are living organisms too. Simplistically this turns into "natural" equated with "good" and human activity as "synthetic" equated with "bad". This view is self evidently, a version of original sin. However child death, starvation, plague, cholera or even SARS are all the results of natural activities; and in contrast, synthetic activities, such as architecture, painting, music and literature are all man-made.

The limitations of this view can be exposed by comparing a natural pesticide with its synthetic equivalent. Table 1 makes some limited comparisons between mancozeb, a synthetic copper fungicide usually used to treat late blight, and the organic pesticide equivalent, copper sulphate. The full table can be found in Leake (1999a). In environmental qualities, mancozeb is superior in all categories compared to copper sulphate. In terms of human health, copper sulphate is corrosive and toxic and has caused liver disease in European vineyard workers. Although the EC theoretically banned copper sulphate in 2002, no alternative has been found for organic farmers and thus it continues to be used. The consequences of not using copper sulphate properly have been reported as organic farms acting as repositories of late blight, a serious disease of potato (Eltun, 1996; Zwankhuizein et al., 1998) or seriously damaged orchards (Van Embden and Peakall, 1996). Any sensible approach would determine use based on toxicity.

Table 1
A comparison of the human and ecotoxicity of mancozeb and copper sulphate

	Mancozeb	Copper
Human health		
LD_{50}	> 5000 mg/kg	50 mg/kg
EPA class	Practically non-toxic	Corrosive and toxic
Health effects	Non-toxic by oral route	Kidney and liver damage
Ecotoxity		
Earthworms	Low toxicity	Very toxic
Birds	Low	Moderately toxic
Small mammals	Non-toxic	Harmful
DT_{50}soil	6–15 days	Non-degradable

Mancozeb is a synthetic copper fungicide used for treating *Phytophora infestans* (potato blight) in particular, and its organic equivalent is copper sulphate. The full table can be found in Leake (1999a). Mancozeb is clearly less damaging than copper sulphate.
Any organic pesticide has a 1 in 2 chance of being carcinogenic at high concentrations (Ames and Gold, 1999, 2000).

Other organic pesticides such as soap (produced from animal fat with alkali) hardly merits the term natural. Rotenone, another organic pesticide, has been recently associated with Parkinsons disease, and another, Bt spores, used to kill insects has been associated with damaging respiratory effects (Trewavas, 2001). Synthetic pyrethroids can be as unstable as the organic pesticide, pyrethrum, but work at much lower concentrations. How natural are the organic pesticides sulphur or oil when they have to be mined, chemically modified or distilled before use?

Agriculture tends in one sense to mimic the effects of individual tree loss in forests. When a mature tree falls over, light penetrates the forest floor, there is flush of nitrate and water in the soil. Weed seeds, which are sensitive to light and/or nitrate, germinate. Most crops are derived from weeds although their germination requirements for nitrate and light have been bred out. Farmers mimic tree loss by clearing ground. The assumption that nitrate is somehow an un-natural fertiliser is contradicted by this perfectly natural process. But the farming activity most deserving the term natural is no-till agriculture which mimics in part the annual cycle of the meadow or prairie.

3. Comparisons of organic and conventional soil properties

The development of thin film technology several decades ago for growing greenhouse crops demonstrated that soil is not actually essential for good crop growth and that only minerals are actually required for active and healthy plant growth (Jones, 1982). Aeroponics using misted mineral solutions generates the most abundant and healthy root systems (Soffer and Burger, 1988). Nevertheless most crops will continue to be grown in soil.

3.1. Is a low organic yield more natural?

From many reports it is clear that organic yields are usually lower, the extent depending on the crop. Leake (1999a, b, 2000,a, b) at CWS agriculture using fields at the same farm reported that organic wheat, beans and peas yields were 60–70% whereas oats were 85% conventional yields (Table 2). Such measurements have been repeated on numerous occasions with variable results. Usually organic yields are much lower but occasionally they can match conventional productivity in a single year. But most organic farming involves a ley period in which clover or alfafa and grass is grown to allow nitrogen fixation and provide the soil with nitrogen once ploughed in. No organic yield is obtained throughout the ley period unless it is grassed and used for cattle, whereas in a conventional farm the same field can be in use continuously for arable crops. Many organic farmers use a field twice for arable crops after the ley period and since in the second year less nitrogen is available, the yield further diminishes. Thus occasional claims that yields can be the same as a conventional farm may only be true one year out of three. It is important to compare total yields over a number of continuous years, not on a single year. Thus Drinkwater et al. (1998) claimed that organic and conventional corn yields were identical without clarifying the necessity for twice as much land to achieve that yield (Sinclair and Cassman, 1999). The Boarded Barns (2000) study routinely reported organic wheat yields using animal manure of about 50% conventional production. Winter wheat is still the staple of most UK arable farming.

Table 2
Typical yields of the major crops grown conventionally and on Soil Association licensed organic fields on the same farm and using the same farmer

	Winter wheat	Winter oats	Winter beans	Dried peas
Organic	4.82	4.87	2.60	2.13
Conv.	7.12	5.75	3.60	3.47

Leake (1997, 1999b). CWS experiments, 1989–1996.
Data compiled from Leake (1997, 1999b).

Such yield differences indicate that organic farming uses good farmland less efficiently. Instead an equivalent yield to organic farming could be achieved on less conventional farm land and the remainder (20–50% of the farm) more profitably employed as woodland, or in willow plantations for bio-fuel (Bertillson, 1992; Trewavas, 2001), (thus recycling carbon) or returning it to other natural conditions such as fenland. These considerations of efficiency are much more important overseas where growing populations using inefficient organic agriculture, will simply cut down more tropical forest than they need to feed the growing population. Currently, for example, Mexican peasants destroy 3 million acres of virgin tropic forest/year to slash-and-burn agriculture (Gregory et al., 2002).

However the UK government has signed up to a protocol to ensure that 10% of all fuels used in the UK by 2010 come from natural sources such as ethanol, thus ensuring that carbon is recycled. On this basis wheat is likely the source for fermentative ethanol production and increasingly, intensive agriculture the likely means for its production.

3.2. Why are organic yields lower?

One reason has to do with the prohibition on the use of very soluble fertiliser. There is a major surge in crop growth suddenly in late spring and mainly in leaf production. Leaves are the most nitrogen-rich tissue in a higher plant and consequently there is a relatively sudden heavy requirement for nitrate to produce leaf protein for chloroplasts and photosynthesis. The vegetative reserves laid down during canopy expansion help provision the seeds when they form. Therefore maximal seed yields are likely to be obtained only when the provision of soil nitrate and the associated crop requirements for leaf production are synchronised. This temporally uneven requirement for N in springtime only can be matched by careful application of very soluble fertiliser.

However a process that ploughs in material which is only slowly degraded over many months or even years cannot release minerals in the short intense burst as required for plant growth. Provision of nitrogen by decay of organic material (mineralization) throughout the season produces nitrate when it is little needed and does not provide sufficient when it is. Furthermore mineralization is greatly speeded up when the field is ploughed, months ahead of the time required by the crop.

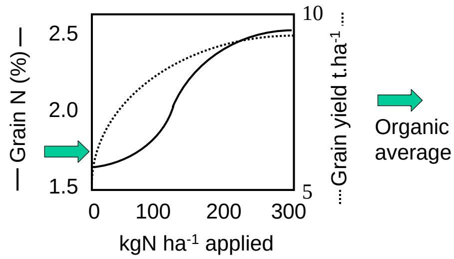

Fig. 2. Does the supply of available nitrogen restrict organic productivity? The graph shows estimates of wheat grain N (%) and grain yield against N applied to the soil. The organic average yield obtained when the organic soil measurably contains 300 kgN/ha is indicated by an arrow and suggests that most N in organic fields is not available when the crop most needs it in spring. The figure is adapted from Berry et al. (2002).

In a detailed examination of mineral availability, Berry et al. (2002) determined the grain N as a % in wheat, the grain yield and inorganic fertiliser applied (Fig. 2). Their comment is that although the amount of N in organic soils should be equivalent to 300 kgN/ha based on soil analysis, organic wheat plants act as though there is only about 50 kgN/ha available for growth and seed formation. Berry et al. (2002) also indicate that the common practice of applying manure or slurries to ley legumes simply diminishes the amount of N fixed by the legumes resulting in a waste of manure. More crucially these measurements indicate that overall analysis of N on organic soils is misleading when such a mismatch between unavailable and available N is so clear. It also suggests that excess N in organic soils, as reported by Watson et al. (2002), appears at the wrong time of year and is likely to disappear into waterways and courses since it remains unused by the crop. Since organic regulations stipulate the use only of supposed natural minerals that decay slowly and are therefore weakly soluble, general mineral analysis might well prove entirely misleading as to how much mineral such as phosphate is actually available to crop plants during the current season.

Ecologists regard fitness as usually measurable in terms of seed yield (Bazzaz, 1996). On this ecological basis, conventional farming produces fitter plants than organic agriculture.

3.3. Is soil fertility better on organic farms?

One of the claims of organic agriculture has been the supposed benefits of organic regulations to soil fertility and soil structure. A series of reviews on organic soils constructed by organic and conventional researchers and published in Soil Use and Management 2002 (Vol. 18 supplement) clarifies the situation. The concluding and summarising chapter (Stockdale et al., 2002) states that "Soil fertility is defined as an ability of a soil to provide the conditions required for plant growth", a view echoed by Russell and Voelcker (1936) much earlier. Given the complexity of soil attributes which modify plant growth and yield and with each crop having different optimal soil requirements, it is doubtful if a more precise definition can be constructed. Critically, crop plants interrogate the soil in which they live and then respond accordingly. In the wild, many types of soil are occupied by individual species, and plants have developed necessary control systems to mitigate some of the variations they come across. If conventional soils were poor from a plant point of view, this would result in poor yields and clearly they are not.

After a detailed consideration of soil organic matter, minerals and nutrients in labile mineral pools in soils, Stockdale et al. (2002) also conclude that "Although nutrient management in organically managed soils is fundamentally different to soils managed conventionally, the underlying processes supporting soil fertility are not". But ploughing in of legume rotations in organic farming provides substantial amounts of soluble minerals to the soil since the vacuole of each cell of a mature plant contains mM concentrations of soluble calcium, magnesium, phosphate and 2–300 mM potassium chloride. Therefore the nutrient management processes are not completely different.

3.4. Is organic soil structure better?

The assumption is that organic farms using organic material added back to the soil must produce a better soil. It should be added that the criteria used to define a good soil are those of the soil scientist, not that of the individual crop plant which may have a very different perspective.

However a review of the literature and an examination of some 30 soils in the UK in organic and conventional farms by Shepherd et al. (2002) led to the conclusion "it is not the farming system per se that is important in promoting better physical conditions but the amount and quality of organic matter returned to the soil" Surprisingly few differences in organic matter content were found between organic and conventionally managed pasture soil, and only trivial differences in 20% of the soils between conventionally managed and organically managed arable soils were detected, usually it seems on stockless conventional farms where differences might be more likely. There is a large background of soil organic matter regardless of farming system deriving from crop roots and root exudates.

No consideration seems to have been given in the reviewed literature to the need for careful matching of managerial standard in the comparisons made by Shepherd et al. (2002). But best-practice, mixed IFM farms will equally apply manure to the soil when they have it and in this case no meaningful difference between IFM and organic soil is likely. The literature is ambiguous and what differences emerge can usually be accounted for by different rotations and different tillage practices. But tillage practice is a choice made by the farmer and a conventional farmer can as easily add organic material to the soil as an organic one. There is no need to change agriculture radically to ensure that this is done; merely pointing to the saving in fertiliser costs should provide sufficient impetus. Managerial quality or choice, not farming mode, is the determinant of soil quality.

3.5. Do organic soils have greater microbial diversity?

If there is greater amounts of organic material in the soil it is usually assumed that this will be accompanied by higher microbial numbers since most soil microbes are heterotrophs requiring organic compounds for growth. Whether higher microbial numbers are actually beneficial or merely asserted to be beneficial seems unclear. But the evidence on microbial populations is conflicting and ambiguous and no clear picture emerges as to whether there are distinct differences in the size, composition, biodiversity and activity of the soil microbial biomass attributable to farming management practice. Recently summarised data (Shannon et al., 2002) indicates that microbial mass was higher in IFM soils (with conventional soils identical to organic ones) whereas fungal mass was higher in organic soils.

But is there any observable benefit in greater diversity? Very large number of microbes are only required if organic material has to be broken down to provide minerals for plant growth. An inability of organic farming to provide sufficient N at the time required suggests there are probably, in relative terms, insufficient microbe numbers.

3.6. Do conventional farms pollute waterways with nitrate and organic farms do not?

Two substantive investigations indicate that nitrate pollution from organic and conventional farms are effectively identical. The first of these (Pickett and Goulding, 1999) reported nitrate leaching through two ley periods followed by three arable periods and showed that when averaged over the 5-year period, nitrate-leached losses were identical at about 50 kg/ha. Stopes et al. (2002) found that "nitrate losses following arable crops averaged 47 and 58 kgN/ha for organic and conventional fields, respectively, following arable crops with part of the difference being due to the greater proportion of non-cereal break crops in the latter". Clearly there were difficulties in matching farm management. These figures are little different to those described by Pickett and Goulding (1999). Nitrate losses during the organic ley phase were similar (45 kg/ha) to those from conventional long-term grass receiving fertiliser levels below 200 kgN/ha (44 kg/ha).

3.7. Do soluble minerals damage the soil?

The Broadbalk experiment has now lasted 160 years being started in 1843 by Lawes and Gilbert (Broadbalk, 2002; Rasmussen et al., 1998). In two sections of this experiment, winter wheat has been grown continuously on land either given only manure (35 tonnes/ha) or only mineral fertilisers. This far-sighted experiment, still of direct relevance to sustainable agriculture concerns, has shown that the yields from the two treatments have remained identical for 160 years. Yields have changed in parallel in the two sections with the introduction of new winter wheat varieties, herbicides, fungicides and all the constantly improving agronomies that are now part of farming. It is quite clear from these data that, within the confines of the experiment, *conventional agriculture using minerals is sustainable*; 160 years is long enough. The soil carbon content has increased in the manure-only treatment by more than two-fold but this has not enabled a higher yield to be obtained (Johnston, 1991). The soil carbon content has increased in the minerals-only treatment by about 20%, the result of leaving root material in the soil. Whether such equivalence in yields over 160 years would be obtained with other crops is not known but the experiment makes the critical point; that soluble mineral-only treatments do not damage the soil from the point of view of the crop plant. However no current farmer in the UK would use a system without rotation and therefore this aspect of the Broadbalk experiment does not now accurately mimic either conventional or organic farming. Pests are better dealt with by rotating crop use. Furthermore identical yields between the manure-only and mineral-only section were obtained by using very large amounts of manure (35 tonnes/ha). But the consequence was that nitrate run-off from the manured section was much higher than the mineral-only section.

The question of sustainability was also examined with other long-term 50-year experiments at Woburn and Saxmundham which commenced in the 19th century and is described in detail by Johnston (1991) and by Russell and Voelcker (1936). These experimental set-ups used either single continuous winter wheat or the Norfolk four course rotation. But similar results were obtained; use of mineral salts-only compared to manure-only did not diminish yield in relative terms.

3.8. Is mineral recycling on organic farms sustainable?

A well grown crop of potatoes, (60tonnes/ha) for example, if sold, removes from the farm 29, 338,12, 4 and 5 kg/ha of P, K, Mg, Ca, Na in the tubers *which must be replaced* otherwise the soil is mined and becomes seriously deficient as are found in many present day African soils. There are currently two primary sources permitted by UKROFS (UK organic regulations).

1. Organic regulations list mined $CaCO_3$ (chalk), KCl (sylvanite), $MgSO_4$ (kaiserite), rock phosphate, trace elements and eight other non-renewable inorganic chemicals, all for a claimed chemical-free agriculture. Such materials have to be mined and transported but the energy costs of transport are usually ignored in energy assessments even though rock phosphate originates in Africa. The lack of purity of such crude mineral sources does not seem to concern organic regulatory bodies. Rock phosphate allowed under organic regulations contains much higher levels of cadmium than purified conventional P (Kirchmann and Thorvaldsson, 2000). There is concern over the potential deficiency of micro-nutrients in organic food such as selenium. There are no stated selenium deficiency symptoms for crops but serious consequences for selenium deficiency for human health (Ames, 1998). Recycling on the farm itself, the supposed goal of organic farming, will not amend this situation.
2. The second source is manure and/or hay from intensive agriculture. Although organic regulations stipulate that such products should come from extensive agriculture, this conflicts with a requirement to balance the number of animals on every farm to the manure requirements so that no excess organic manure is produced. In this situation organic agriculture becomes dependent on intensive farming, a form of farming it considers unsustainable. But in the absence of conventional farming, organic as presently constructed will be completely unsustainable too.
3. A further source of minerals is purchased animal feed. But this again is produced from conventional agriculture using minerals. However organic regulations would not permit this source of minerals in animal feed for general use leading again to questions over sustainability.

There are some minor additional sources of organic material for organic farming and these include bone and blood meal (BSE free?) or seaweed extracted with acid or alkali! Why rock phosphate treated with acid to form super-phosphate for conventional agriculture is discriminated against, when acid treatment of seaweed containing organic and inorganic phosphate convertible to super-phosphate is allowed is not clear and reflects arbitrariness in the construction of regulations.

When examined, slow declines in the mineral content of organic soils can be detected particularly in K and P (Topp et al., 2000; Trewavas, 2001;Watson et al., 2000). Analysis for available P and K indicated that 86% organic soils examined were deficient in P and 36% deficient in K. Only 15% of conventional soils were deficient in P and 30% deficient in K (Goulding et al., 2000).

Conventionally generated manure uses soluble minerals for the production of animal feed in the form of wheat or corn. The energy costs of producing minerals for animal feed (often commented on) are simply carried through to the energy costs of producing the same amount of K, N or P in manure (often ignored).

Recent detailed analyses of many field soils on a metre-by-metre basis indicate substantial variability in mineral content and yield of individual fields (Goulding et al., 1999; Smil, 2000a, b). Because dumping manure requires more labour than distributing minerals, it has been found that fields on some organic farms farthest from manure heaps are the least treated and experience most deficiency. Congregation of animals causes further uneven distribution which can last years. Such maldistributions make calculation of available N on organic farms very uncertain which overall assessments of the whole farm do not mitigate.

Watson et al. (2002) in an analysis and review of organic farm budgets and mineral recycling conclude "The data presented here also suggest some cause for concern in relation to sustainability of organic dairy systems because of their dependence on imported feedstuffs and bedding for P and K and for N on the very variable fixation by legumes of imports of manures or composts". On its own then, organic farming is not sustainable except as part of another form of agriculture on which it is actively dependent and which it opposes. Either the lack of sustainability will have to be recognised or organic will have to import minerals of one sort of another which due to slow breakdown will cause problems in matching requirements with yield as figures already indicate. In that case organic farming will no longer be able to claim to be chemical free. The notion that organic farms can operate as small, totally self-contained entities is simply a delusion.

3.9. *Is manure better than minerals?*

Analysis of manure indicates the presence of extensive amounts of the soluble minerals (such as K) which are prohibited under organic regulations. But these minerals will simply wash into the soil and be easily lost unless applied to a growing crop. Potassium chloride (sulphate, phosphate or nitrate) is no less soluble in manure than it is in soluble fertiliser form. Loss of N in ammonia from fresh manure represents waste and at least half of the manure N can be lost during composting from volatilisation (see references in Kirchmann and Thorvaldsson, 2000). But composting is essential to eliminate dangerous organisms. It is a common assumption that in some way manure contains no chemicals and that therefore organic farming is somehow chemical free. But fresh manure is known to contain mercaptans, aliphatic aldehydes, organic acids and lipids, phenols and *m*-cresol, various amines etc. (Hankins et al., 2000; Koelsch, 1995). A full analysis of all the chemicals in manure seems currently to be unavailable but based on previous experience at least half of these organic chemicals are carcinogenic in rodent tests. The major constituents of manure are lignin and cellulose break-down products. Overcash et al. (1983) and Eghball and Power (1990) provide detailed analyses of different manures indicating that all the major (N, P, K) and some of the minor minerals can vary 10–30-fold in different manures. Such variation is a further cause for concern, matching those expressed above for using only legumes for nitrogen production.

It is well known that farm animals shed dangerous organisms from their gut and cases of *E. coli* 0157 and Salmonella poisoning from manure contamination are well established (Trewavas, 2001). Although composting manure can destroy microorganisms, the process is arbitrary and uncertain as it is dependent on the shape, volume, position and time of composting. Killing dangerous organisms in manure heaps is dependent on critical temperature (usually 60°C) being reached and maintained for 90 days. There is no simple way of determining this temperature/time requirement and temperatures at the compost surface are usually lower than inside. The destruction of food-poisoning viruses (such as the Norwalk-like viruses) has not been examined at all although such incidences of virus-induced poisoning are suggested to be increasing. Child death from eating organic parsley has been reported in the medical literature (Tschape et al., 1995). While problems with manure apply equally to conventional mixed farms as well, a conventional farmer can use manure just as a soil conditioner and provider of organic material to improve soil crumb structure. Such farmers are therefore not under the same pressure as an organic farmer who needs to apply manure quickly to the soil before much of the N disappears into the atmosphere as ammonia and probably nitrous oxide.

Neither organic nor conventionally grown foods are free from pesticides but the health risks are considered to be higher from food borne pathogens than pesticide residues (IFST, 2003).

3.10. Conclusion on organic soils

The UK Ministry of Agriculture concluded in 1999 that organic farming brought environmental benefits which included improved soil quality and reduced pollution. Like many others the conclusions are probably 30–40 years out of date because conventional agriculture has greatly improved as a result of information provided from research and consultant agronomists. This section on soils indicates that little or no benefits follow from current organic procedures compared to other kinds of farming and that the assumptions that underpinned Balfour's (1948) concerns, for example, no longer exist in substantive amount in the UK. Indeed the indications are that organic farm problems will instead accumulate for the future particularly as regards mineral recycling. Perhaps more crucial is that the supposed destruction and erosion of the soil in the UK is no longer occurs and the case for supporting organic agriculture on this basis is not justified.

4. Is organic food more nutritious, healthier and tastier than conventional products?

Many taste assessments of organic and conventional foods have been properly made. In these the individual is provided with three pieces of the same produce and asked to state which two are the same. Such tests have indicated that there is common confusion of freshness for organic produce and that the public cannot easily distinguish organic from conventional (Hansen, 1981; Basker, 1992).

Although it has been claimed that organic produce is healthier food than conventional produce, the current evidence does not support this contention. Most papers indicate that the composition of organic produce is not significantly different from conventional food (Bourn and Prescott, 2002; Newsome, 1990; Williams, 2002; Woese et al., 1997; Worthington, 2001). Mineral composition of conventional food can vary very substantially, dependent on conditions of growth, (Goodall and Gregory, 1947). Summaries from nutritionists and others indicate that occasionally there may be slight increases in vitamin C although the figures are not particularly consistent and are strongly biased by two isolated measurements by Schupan (1974) many years ago in lettuce and cabbage. However vitamin C may accumulate when oxidative stress is experienced, a consequence of disease and perhaps deficiency. Mutation rates and DNA rearrangements may also increase as a result of stress and disease, as has been observed (Kovalchuk et al., 2003).

There is no indication however that the UK public is in anyway short of vitamin C; in fact current consumption levels of 70–90 mg/day are close to the renal plasma clearance value of about 100 mg/day, (Department of Health, 1998). WHO recommendations are for 45 mg/day. At least 30 chemicals or additives are allowed and used for organic food processing (Farm and Food Society, 1999), a fact not commonly known.

Bourn and Prescott (2002) conclude that "with the possible exception of lower nitrate levels there is no strong evidence that organic and conventional food differ in their concentration of various nutrients. While there are findings indicating that that organic and conventional fruits and vegetables may differ in a variety of sensory qualities, the findings are inconsistent.'' They suggest that freshness is an important criterion often confused with organic food because of its local sourcing.

Williams (2002), a human nutritionist, concluded ''there appears to be a wide-spread perception amongst consumers that such organic methods result in foods of higher nutritional quality. The present review concludes that evidence that can support or refute such perception is not available in the scientific literature.'' Occasional attempts have been made to compare health outcomes between those only consuming organic or conventional produce '' Comparison of health outcomes in populations that habitually consume organically or conventionally produced foods are flawed by the large number of confounding factors that might contribute to the differences reported.'' Different conditions of cultivation could well give rise to pronounced variation in the chemistry of the food produced and, in particular, Williams (2002) suggests that stress for organic plants might well be a problem, inducing the formation of a variety of chemicals whose total contribution to human health is simply unknown. Given the wide variety of ways in which even organic farms are run it is unlikely that any standard guarantee for food quality can be produced. Organic is a mechanism or process; it does not guarantee the product. Managerial quality seems equally important (Bourn and Prescott, 2002).

It needs emphasising in conclusion that if the composition of organic food is different, particularly in secondary products, there can be no guarantee of long term safety because human disease and mortality statistics to justify the safety of organic food are not available. In contrast substantive information on the consumption of conventional fruit and vegetables and such statistics are present in abundance.

5. Is organic farming environmentally superior?

It is a common assumption that organic farming is better for the environment; but better than what? It depends on what is considered the most valuable criterion of environmental benefit and that is not easy to define. Nor do the actual results support any simplistic view. In order to reduce managerial differences I have referred initially to studies on the same farm run by the same farmer and discussed others later.

5.1. Measurements on the same farm

The Boarded Barns (2000) study reported that 80–85% of biodiversity on any farm existed in the field margins and hedgerows. Measurements covered small mammals, collembola, (mites that damage pests), micro and predatory arthropods, predatory beetles and birds. What was in the cropped area was of little overall significance for biodiversity (Higginbotham et al., 2000). Thus any farming mode that maintains margins and hedgerows (such as IFM practiced by LEAFUK.org; Drummond, 2000) is likely to be as good as any organic field and the effects of pesticide application on the cropped area of little significance. In the Boarded Barns study, small mammal activity examined wood mice, bank voles, common shrews. Based on trapping, activity and diversity was identical between organic, conventional and IFM farming. In Collembola (predatory mites) the only significant change was a higher proportion of individuals on IFM soils, conventional and organic being the same. Species richness was also similar. Earthworm densities were highest in the no-till IFM fields with organic second at about twice that of conventional fields. Numbers of earthworm species were however similar. [But these differences were nowhere near those observed between long-term no-till to till in which those under no-till were six-fold higher, particularly in the large *Lumbricus terrestris* species]. Microarthropods were five-fold higher on IFM fields than organic or conventional fields (Higginbotham et al., 2000). The numbers of predatory arthropods, in particular carabid beetles, were however higher (about 25%) on organic soils. But the crop in the field played a greater part in carabid variation than the mode of agriculture, being four-fold higher in bean crops than wheat. In these measurements organic wheat had only one half the numbers of carabids than conventional wheat.

5.2. Measurements comparing different farms

Similar reports of higher numbers of carabid beetles on organic fields have been reported in a number of investigations, (Basedow, 2002; Clark, 1999; Dritschilo and Erwin, 1982; Dritschilo and Wanner, 1980; Good and Giller, 1991; Hokkanen and Holpainen, 1986). For example Shah et al. (2003) found three-fold higher numbers of carabids but almost all was due to much increased numbers of only one species of beetle, *Pterostichus melanarius*, the common black beetle which also eats earthworms (Symondson et al., 2000). However Armstrong (1995) detected no differences in potato crops suggesting crop variety may be more important than mode of agriculture as was found in the Boarded Barns study.

Ground beetles are much easier to capture which accounts for their popularity in measurement, but using vacuum collection other kinds can also be surveyed but the measurements are few in number (Moreby et al., 1994). The numbers of Staphylinids, (winged predatory beetles), Coccinellids (lady birds) and Cantharidae were very substantially higher in conventional fields (Moreby et al., 1994; Shah et al., 2003) as were all other measured beetle classes apart from Carabidae. Moreby et al. (1994) indicated that some of their measurements comparing organic and conventional fields were made on the same farm and thus would satisfy the requirement of managerial equivalence.

Feber et al. (1997) compared butterfly numbers on organic and conventional farms and found more on organic farms of the non-pest variety although differences varied with the crop and the year. Thus the authors concluded that crop patterns not mode of agriculture might be the over-riding determinant. Perhaps this is similar to the crop effects on carabids described above. No comparisons were made with IFM farms and since field margins and hedgerows are similar between organic and IFM farms, butterfly numbers relying on these undisturbed parts of the farm are unlikely to be different.

5.3. *Biodiversity indices of invertebrates on organic and conventional fields*

Whether having more of one particular species of beetle makes the ecosystem more or less stable is very unclear. However application of measures of biodiversity (the Shannon-Weaver index for example) in Shah et al. (2003) indicated the highest beetle biodiversity to be on conventional fields. All others have reported the same outcome using biodiversity measures (Clark, 1999; Dritschilo and Erwin, 1982; Dritschilo and Wanner, 1980; Hokkanen and Holpainen, 1986). That should not be a surprise, there is a more uniform distribution of numbers between different beetle species on the conventional fields. Greater diversity tends to be found in stressful situations with pesticides providing the stress. If diversity is related to stability then the conventional field may be classed as more ecologically stable. Foster et al. (1990) reported that water beetle fauna of higher quality and quantity were found now in 1990 than in 1938 when synthetic insecticides were not in use. Water beetles are sometimes used as indicants of water quality (Eyre, 1998).

Deep ploughing (as required on organic farms) can disrupt the carabid community (Dritschilo and Wanner, 1980), and no-till methods will leave the highest numbers (Kromp, 1999) with reported increases anywhere up to 20-fold down to zero. Hedgerows, beetle banks and conservation headlands (Kromp, 1999), all part of IFM (Drummond, 2000) increase carabid beetle numbers.

Other insects were also surveyed by Moreby et al. (1994). They found higher densities of nematocerean and acalypteran diptera, hemiptera (especially aphids), aphid specific predators, parasitic hymenoptera as well as most beetle fauna in conventional fields. Higher densities of weevils, spiders, springtails, plant hoppers and sawfly larvae were found in organic fields. Moreby et al. (1994) conclude that "although some significant differences in density of some arthropods were found in organic fields of winter wheat, one of the most striking observations was the lack of large scale treatment differences that were expected from such fundamental differences in the use of pesticides and different approaches to crop rotation and soil cultivation".

5.4. *Bird populations*

Declines in numbers of particular bird species normally found on both UK farmland and gardens have been reported in the last 30 years (Fuller et al., 1995) and intensive agriculture has been blamed by some for this situation. However the situation is complex and to claim that it is just changes in farmland management is simplistic. Declines in birds that live in at least equal numbers or more on habitats other than farmland have also been observed (Gregory and Baillie, 1998). In fact the major questions that must be raised are why should anyone consider that bird populations remain constant (Sharrock, 1999), given that in the past enormous fluctuations in population numbers have been recorded for birds such as the tree sparrow (English Nature, 1998). As regards declines in common garden song birds, the domestic cat population (thought to be about 8 million and to have increased in number by 50% in the last 20 years) has been estimated to eliminate some 300 million young birds and small mammals, such as dormice, every year. The feral cat population estimated at about one million individuals, will also inflict substantial (and probably even greater) damage but the extent is completely unknown. There have also been substantial increases in the population of predatory birds such as magpies and carrion crows (Gregory and Baillie, 1998), probably the result of increased car traffic and dead birds and mammals on roads and roadsides. All of these influences may play some part, but it is incorrect to ascribe cause and effect to just farming particularly when bird numbers are a complex system known to result from many interacting factors.

Arable farming occupies about 30% of the agricultural land surface of the UK. The tendency to blame farming for variations in bird numbers followed directly from Carson's, 1962, "Silent Spring", a title referring directly to bird populations. The assumption was that pesticides would eliminate birds by poisoning and that population numbers would drop linearly with increased pesticide use. But habitat loss is just as likely to affect bird numbers as it was in Carson's time. Direct evidence established by the Game Conservancy on the grey partridge has identified particular conventional farm practices with declines in numbers but this is the only bird that has substantive science behind it; the rest is largely speculation. However whereas there have been declines in some 13 farmland specialist species, there have been increases in 14 farmland generalist species; increases in, for example, goldfinch, chaffinch, black cap or great tit (Siwardena et al., 1998). Tree sparrows have decreased by 50% in the last 30 years whilst unsurprisingly and perhaps causally corresponding numbers of sparrow hawks have increased 50%.

The Boarded Barns (2000) experiment measured the territories of 13 bird species continuously over 9 years and found, intermittently, slightly higher levels of birds over the organic fields, although at the end of 9 years no difference in numbers was observed (Higginbotham et al., 2000). In the most intensive study on birds reported by the British Trust for Ornithology, (BTO, 1995), 22 farms of organic status were compared with nearby conventional farms. However no attempt was made to match managerial competence and the investigators admitted that in many cases conventional arable farms were matched with mixed organic farms, (BTO, 1995). While bird numbers on organic farms exceeded those of conventional farms in 50 of 68 individual cases, statistical significance was only established for two species (Chamberlain et al., 1999). Much of the variation was attributed to field boundary effects and to hedgerow height and width (Chamberlain and Wilson, 2000, Chamberlain et al., 1999), aspects of the landscape which are not unique to organic farms but are shared equally by IFM (Drummond, 2000). However the benefits of organic farming to birds in terms of biodiversity and numbers were only present in one year out of three (BTO, 1995). There is a common trend for slightly higher numbers of birds to be present on organic farms during winter but these ambiguous changes are not in any way matched by observations that no-till fields gave rise to orders of magnitude higher bird numbers compared to tilled fields in winter months (Higginbotham et al., 2000).

IFM regulations advise on hedgerow maintenance and field margin width identical to organic regulations. So any increase that can be ascribed to organic should be equally shared by IFM farming except where no-till is employed where it may be higher again. Deliberate manipulation of conventional farming practice at Allerton increased bird population numbers by over 40%, substantially more than the minor differences noted on organic farms as compared to conventional farms (Boatman and Stoate, 2000; Stoat and Leake, 2002). Those measurements indicate the potential available on any farm.

5.5. Conclusion on environmental issues

In conclusion it would be difficult to make a case for organic farming on any reasonable basis for environmental benefit compared to well-managed conventional or integrated farms. There are clear indications that the type of crop can be important as well as management strategy. Hedgerows and field margins can be legislated on, as is the condition of set-aside. In fact legislation on the use of set-aside to farm natural birds, as it were and increase their numbers, seems lacking despite the land area which is currently available. What is surprising is that the received wisdom that organic must be better for the environment, in general, because it does not use synthetic pesticides, simply does not stand up to rigorous investigation. Or perhaps we should not be surprised. The environment is complex, its ecology is not well understood and frequently in these complex networked systems the results are often counter-intuitive.

The data that indicates biodiversity is higher on conventional farms should again not surprise since populations under mild stress are usually richer in numbers of species. Certainly that was the conclusion many years ago of plant species on grassland treated or untreated with fertiliser. The untreated land was regarded as stressful to the plant species present. The data previously referred to for no-till agriculture indicated the clear superiority of this form of farming in environmental measures. An examination of management schemes to improve biodiversity in Holland found no improvement (Kleijn et al., 2001).

6. Changing to organic farming would lower costs of agriculture

Pretty et al. (2000) estimated the externality costs of UK agriculture. However the paper omitted any attempt to compensate the costs with estimates of the benefits of (a) food security supplied by UK agriculture, (b) the improvement of life expectancy of which certainly, a portion has come from a reliable food supply. In one sense, the article is therefore a critique on only the costs of UK agriculture and particularly its conventional version and critics of conventional farming have used it as such (see Maeder et al. reply to Goklany, in Goklany et al., 2002).

One component of these externalities estimated by Pretty et al. (2000) was the supposed costs of pesticide removal from river water. However these proved instead to be the cost of constructing, improved, water purification plants to fit in with new EC water purity regulations; largely to remove nitrate and reduce eutrophication in rivers and lakes. But as has been seen above, current organic farming procedures will represent no improvement in this respect. Besides the EC regulations are considered by many excessive and unnecessarily stringent. The justification on health grounds for lowering nitrate levels in tap water is certainly questionable (Trewavas, 2004).

The costs estimated by Pretty et al. (2000) were for 1997 only and the paper states that the expense of removing pesticides from river water is about £120 million/year. A question in the House of Commons on 3 April 2000 showed that this figure was correct for 1997 but had dropped to only £11 million in 1999 and presumably to zero thereafter (United Kingdom Parliament, 2000). The Minister involved (Mullin) stated that no figure was actually available for purification running costs, only for building. And anyway water has to be purified; one cannot segregate purification requirements of any one chemical from the many others to be found in sewage.

Whether the EC regulations were in any way necessary, because they were based on incorrect assumptions, should be considered. Nitrate was commonly used as an analgesic before aspirin became readily available. The scare story surrounding nitrate and nitrite has been shown to be false (L'Hirondel, 1999). Also Knutson (1999) performed a detailed study of the costs to human health and the economy of removing pesticides from agriculture. The costs of removal were much greater than the benefits.

Pretty et al. (2000) estimated that half of the externality cost of agriculture came from the production of carbon dioxide, nitrous oxide and methane and the resultant effect of global warming on the environment. Removing the pesticide error indicated above from the figures of Pretty et al. (2000) above and using the gaseous losses determined from each of the main kinds of agriculture (Robertson et al., 2000). I estimate the externality costs/ha/year as £154 for UK conventional agriculture. Equivalent costs for organic, assuming all the UK was organic, would be £79 and likewise £29 for no till. There are about 12 million ha of farmland in the UK and the population is about 60 million. On these figures each person therefore is environmentally costed *£30/year for conventional agriculture, £16 for organic and £6 if it were no-till*. Those bills should be set against the average estimated food costs/person/year of £1500 for conventional, IFM and no-till and *£2100* for organic. The benefits from a secure food supply which conventional agriculture offers cannot easily be costed, because they involve life and death issues.

7. Organic uses less overall energy

There have been claims that organic farming requires less energy because it does not use synthetic fertilisers or pesticides (Maeder et al., 2002a). Bertillson (1992) (see also Addiscott, 1993, 1995) examined the energy costs of various kinds of agriculture and pointed out that the most energy efficient/ha was a conventional farm coupled with willow plantations on part of the farm to provide generating stations with combustible fuel (biofuel). In fact his figures indicated that such farms produced more energy than they consumed. However Bertillson (1992) also provided figures for the use of energy in the production, transport and distribution of fertiliser and these figures are about 10 kWh/kgN. No data is available for the mining and transport of phosphate fertiliser although it seems to be forgotten that organic farming ultimately depends on its use and other fertilisers.

Reganold et al. (2001) made the critical error of assuming that, because chicken manure was purchased from a conventional farm it involved absolutely no energy in its production. Chickens however are fed on diets of conventional corn or wheat which use minerals including nitrate for growth. Only about 10% of the N that is fed to chickens is likely to emerge in manure but every gram of that 10% N in manure costs the same in energy terms as every gram N in the original mineral fertiliser. The energy costs have not disappeared because they have passed through the gut of a bird or been purchased from someone else or described as waste. They are a cost on the worlds energy use; quite simply there is "no free lunch".

Leake (2000a) measured all the draft fuel used on organic, conventional and integrated no-till agriculture over a 2-year period. Expressed as energy used/tonne of wheat yield, organic fields used 3 × as much energy as integrated no-till fields and 2.5 × as much as conventional fields. Much of the extra energy was required for weeding and of course deep ploughing. Although the organic energy requirement can be reduced by using hand weeding, getting labour to carry out this physically damaging activity is not only difficult but extremely suspect from a health point of view. The human spine is known to be easily damaged by continuous bending. One study has also pointed to the likely physical damage of pure organic farming from heavy lifting and excessive and unhealthy labour (Loake, 2001).

Uhlin (1999) estimated that fuel represented 26% of the energy use in conventional farming; fertiliser production only accounted for 14%. Putting the Bertillson figures (for fertiliser and transport) with those of Leake (2000a) on fossil fuel use on farms and Uhlin (1999) estimates of energy use, the efficiency of conversion of fossil fuel use into seed energy can be estimated. From Table 2, the figures for organic in kWh/tonne of yield of wheat are organic 200, integrated 132, conventional 140. The latter two forms of farming are on this basis more efficient in their conversion of energy into product.

There are several caveats in the figures above. Leake (2000a) used 180 kgN/ha for wheat production (Table 2). Other farmers may use more or less N, dependent on manure input. Leake however states his organic yields are substantially higher than the average UK organic yield. Bertillson (1992) assumed that intensive farming only uses 100 kgN/ha. Thus I have programmed in a worst case scenario for conventional farming. Secondly I have not included any energy considerations for the mining and transport of phosphate rock or transport or packaging of minerals to organic farms. Taking account of these considerations places integrated no-till as about 2 times as energy efficient as organic farming and conventional farming about the same.

8. Benefits to the use of GM herbicide tolerant crops—the superiority of no-till agriculture over organic and conventional agriculture for the environment

"Had we not originally gone contrary to the laws of nature by ploughing the land we would have avoided the problems as well as the time consuming efforts to solve them. We would have missed all of the erosion, the sour soils, the mounting floods, the lowering water table, the vanishing wildlife, the compact and impervious soil surface" (Faulkner, 1943). Faulkner made this statement in his book "Plowmans Folly" which describes his experiences in developing no-till technology. What primarily energised Faulkner was his recognition that the prairies suffered none of the agricultural problems at the time and his recognition that ploughing (the most damaging soil treatment used by farmers) was responsible.

All of Faulkner's claims have been established by measurement and indicate the numerous benefits of no-till agriculture over organic and conventional ploughing technologies. Organic farmers need to plough not only to remove weeds, which accumulate in organic fields, (weed seed density has been shown to be three-fold higher) but to mineralise N and possibly P and S. Thus organic farming shares all the problems that come from ploughing and comparisons with ploughed fields apply equally to them as well as conventional ploughing. No-till agriculture is most easily introduced with herbicide tolerant (HT) crops to avoid weed problems.

No-till has not been greatly used in the UK. DEFRA have issued two booklets describing case histories and indicating that clay soils are best for no-till. (Booklets are "A Guide to Managing Crop Establishment" produced by the Soil Management Initiative and "A Guide to Better Soil Structure" by National Soil Resources Institute.) Much of southern and midland England is certainly suitable for no-till. There have been experiments some 30 years ago in Scotland on no-till but cold soils may have been a problem in its introduction. However Scottish LEAFUK farmers are experimenting with min-till successfully at present. Blackgrass was also a problem in early no-till but that is now controllable with glyphosate. However this would seem to be an area for further research to be undertaken.

I have listed the benefits of No-till compared to till below. Much of the published research comes from the USA but reviews in the UK by Goulding et al. (1999), and experiments of Jordan et al. (2000) are published. Jordan et al. (2000) report measurements on run-off, sediment loss (erosion), free N and P and herbicide disappearance all of which agrees with more detailed data from the USA.

Boarded Barns also used no-till integrated farm management as part of its experiments and other experiments were performed at Stoughton (Leake, 1997, 1999a, b, 2000a, b). However the no-till fields at Boarded barns were only cultivated for 4 years and differences emerging in environmental measurements over a 4-year period are usually insufficient to assess a farming process that requires basically a permanent commitment to no-till on a field basis.

8.1. Advantages of no-till agriculture compared to tilled organic and conventional fields

1. Farm fossil fuel use (on a yield basis) reduced to 1/3rd that of a tilled field (Leake, 2000a).
2. Soil erosion is reduced to 5% of a ploughed field. Soil nutrition, structure and drainage are vastly better and flooding all but eliminated (Fawcett et al., 1994). Preventing sediment losses from erosion greatly improves the local aquatic habitat (Baker and Laflen, 1983). Estimates suggest that erosion causes losses of 9 billion dollars in the US (Ribaudo, 1997). However from 1982–1997, soil erosion diminished by an estimated 30% the result of an extensive introduction of zero tillage agriculture (USDA-ARS, 1997).
3. Run-off of fertilisers and herbicides is greatly diminished (Glenn and Angle, 1987; Hall et al., 1991) and herbicides such as isoproturon when used are no longer detectable in soil drainage (Fawcett et al., 1994; Jordan et al., 2000; Levanson et al., 1993). Rain water preferentially drains through a no-till soil and the longer residence of chemicals in the soil enables microbial action to break them down (Doran, 1980).
4. Free oxidised nitrogen compounds such as nitrate are reduced to 1/5th to 1/20th that in tilled soil and free phosphate to 1/6th (Andraski et al., 1985; Goulding et al., 1999; Jordan et al., 2000). Thus nitrate in waterways is reduced by this amount and far lower than any EC regulations specify.
5. Pest predators (mainly carabids and staphlinids) increase six-fold in number (House and Parmalee, 1985). Biodiversity has not been assessed. These pest predators hide under the vegetation on the surface and are thus largely unaffected by sprays on

the canopy. They are also protected from many bird predators.

6. Large earthworm numbers increase by up to 6-fold (House and Parmalee, 1985). The latter greatly improves drainage by leaving open channels in the soil. In ploughed soils only much smaller worms predominate.
7. Bird territories and bird nests increase anywhere from 3–100-fold (Basore et al, 1986; Higginbotham et al., 2000). The time requirements for young bird feeding are reduced five-fold. These figures contrast quite strongly with the very minor and uncertain differences observed between well-managed conventional farm and organic farms.
8. Small mammals are more abundant in no-tilled fields (Warburton and Klimstra, 1984).
9. Soil moisture is better balanced during drought (Seimans, 1998; Norwood, 1999). Lack of ploughing enables the survival of capillaries that connect the surface layers with water tables at much deeper levels so during drought sufficient water rises up for the growing crop.
10. Soil carbon accumulates in the surface layer and the contribution to global warming reductions can be substantial. However one pass of the plough leads to an enormous increase (14-fold) of carbon dioxide evolution (Reicosky and Lindstrom, 1995). The input of oxygen into the soil enables large-scale degradation of organic material by microbes. Robertson et al. (2000) showed that *no-till has 1/3rd global warming potential of organic* which in turn is about half that of large scale conventional farming in the USA. The precise similarities of US agriculture and UK agriculture are uncertain. Intriguingly these authors also reported that methane and nitrous oxide losses from soil were similar amongst all farming modes although these measurements were made on US farms and could be different in UK soils. Mineralization to produce N for crop growth also requires input of oxygen into the soil but results in inappropriate release when crops are not present to remove free N from the soil (Djuruhus and Olsen, 1997).
11. No-till mimicks seasonal change in soil surface vegetation in both meadow and prairie.

8.2. *Conclusions on no-till*

The advantages of no-till over organic ploughed fields is considerable in terms of wild life, environmental issues such as nitrate pollution and global warming and soil structure. When combined with IFM it is a superior form of agriculture in virtually all respects and *merits much more attention than it currently gets*. GM herbicide-tolerant crops in the USA are responsible for the considerable USA take-up of no-till agriculture.

9. Critical assessment of published organic papers

There have been several papers published in recent years that make claims about the benefits of organic agriculture but much of the comparisons do not use contemporary forms of conventional farming but what might have been present 30–40 years ago. These papers come from Switzerland and the USA both of which have different climatic and farming conditions to the UK e.g. Reganold et al. (2001). However it is well worth while reviewing the paper by Maeder et al. (2002a) critically and in detail as an example.

Maeder et al. (2002a) report on long term (21 year) experiments in which conventional (although claimed to be IFM) is compared to organic and Steiner's biodynamic agriculture. It was reported that higher soil fertility and microbial biodiversity was obtained by organic and biodynamic approaches. However there are some serious criticisms to be made and I have listed these.

1. Maeder et al. (2002a) used biodynamic approaches and followed the proscribed regulations set out by Steiner (1958). As described in the Appendix of the paper these include burying cows horns in which silica is "fermented" and the use of cows or stags bladders for fermenting various plant materials as indicated in Section 1 of this paper. No scientific study worthy of the name should include what are basically occult beliefs in cosmic forces (Kirchmann, 1994). The authors should *either state that they disbelieve the basis of biodynamic farming* or justify their occult view. Why silica is not regarded as a chemical is not clear nor how basically rock is fermented.
2. What is claimed in this paper as IFM would not be recognised as such in the UK (see for example the regulations by LEAFUK.ORG, (Drummond, 2000). Bertillson (1992) more rightly described such approaches as merely low input. Consequently the yields of wheat obtained by Maeder et al. (2002a) although claimed to be representative of the region are only some 40% of what is routinely achieved in the UK. This low input of fertiliser might account for the weak conventional yields described thus favouring the comparison with organic farming. No measurements of nitrate run-off were made.
3. Maeder et al. (2002a) also claim that the organic procedure uses less energy in its production. However without proper use of modern IFM (Sinclair and Cassman, 1999), the draft fossil fuel use might appear to be favour organic farming. But as indicated in this present article using proper modern measurements this claim of Maeder et al. (2002a) can be questioned; organic is wasteful in the use of fuel and on a yield basis is even weaker than conventional farming.

4. Photographs in Maeder et al. (2002a) are used to bolster the notion that organic is better for the soil because of greater carbon content. However these claims are confounded by Shannon et al. (2002) and other measurements in the UK that indicate little or no detectable differences in carbon contents between conventional and organic soils. Also the Broadbalk experiments revealed that enormous differences in carbon content of the soil did not alter yield (Johnston, 1991). Shannon et al. (2002) suggest that because conventional farming leaves root material in the soil and because exudates from the roots account for up to 15% of root dry weight, substantial amounts of organic material are incorporated in every growing season. In addition it is suggested that conventional plants will have larger root systems arising from greater nourishment and this in part balances out any organic material added to the soil such as manure. A single rye plant for example has been estimated to grow 300 miles of root in one season (Torrey and Clarkson, 1975)! However it must be emphasised that many conventional farmers in the UK on mixed farms routinely add their manure to the soil. The advantages of rotation are well understood and used. Continuous monoculture of a single crop is not used in the UK if it ever was. It should be remembered that the standard Norfolk four course rotation was developed in the UK, several centuries back.
5. Although Maeder et al. (2002a) claim that organic soils are more fertile because microorganism content is higher these suppositions must be seriously questioned. Plants interrogate the soils in which they grow and the extent to which they find the soil fertile determines ultimate yield, which is clearly higher on conventional fields. Fertile means quite simply "bearing abundantly" and the ecological term "fitness" is often quoted to equate to seed numbers and size. Conventional plants are then, on these bases, fitter than organic plants as stated before.
6. Maeder et al. (2002a) are trying to impose an inappropriate ecological and artificial supposition on fertility for which frankly there is no evidence. Organic material in the soil improves its friability but that has been known for centuries and mixed farms simply add what they have now to save on fertiliser costs. Like so many assertions what is regarded as better is simply what is thought to be unique in organic systems. In other words prejudgement has replaced unbiased assessment. Shannon et al. (2002) concluded that whatever differences in microorganism content are found in organic soils they are merely subtle. Again it is not obvious what are the real soil criteria that should operate if any should operate at all. More microorganisms in the soil (if they occur) will ensure that when the organic field is ploughed, a greater volume of carbon dioxide will be released and greater nitrate will be leached to waterways.
7. In the last sentence of the paper Maeder et al. (2002a) conclude that organically managed legume-based systems utilising organic fertilisers from the farm itself are a realistic alternative to conventional farming systems. Like so many flimsy conclusions, the assumption is made that organic is more sustainable than conventional farming. But with any farm selling produce, where do the minerals come from that are sold off with the produce? No mention is made in this paper of their sources of minerals! If the produce was merely recycled on the farm trial under investigation then as an investigation it was pointless. If no minerals were added at all then the produce quality and mineral content would likely decline with knock-on effects for human health. If the minerals come from a conventional farm, as most currently seem to, then organic is not sustainable in the absence of conventional farming; it is not an alternative. But if the minerals come from mined non-renewable resources then organic is no more sustainable than conventional agriculture. In that case estimates of energy use in mining and transport need to be included in energy considerations for organic farming. These seem to have been avoided. The arbitrary rules for organic farming in the UK were laid down at a time when it was thought that resources would run out and on that basis organic farms were supposed to be self-sufficient (Balfour, 1948). In fact they cannot be. We now know this was a point of view that was constrained in its formulation and understanding and as indicated in the introduction there is no shortage of resources. If all farming was organic then there would be no animal feed at all and no excess manure. Enormous deficiencies would occur when infectious diseases like foot-and-mouth destroyed substantial numbers of animals.
8. As in so many things the thinking behind organic farming is simply 30–40 years out of date. This was most clearly indicated in the response of Maeder et al. (2002b) to Goklany, (Goklany et al., 2002), to the obvious point that organic farms require more land to generate the same amount of produce. Thus going organic world-wide would level the remaining forests of the world since it is only under forests that any soil that could be used for farming is still present (Gregory et al., 2002). Maeder et al. (2002b) quote Pimental et al. (1995) to indicate their belief that organic leads to greater biodiversity, lower inputs and much lower soil erosion. However the Pimental et al. (1995) estimates of soil erosion in the USA were grossly flawed as pointed out by Crosson (1995) and Trimble and Crosson (2000). Crosson indicates that only 0.07% of USA land is strongly degraded leading

to, at the most, a loss of 5% of agricultural production in the USA. Significant soil losses due to erosion are not now found in Europe but do occur as a result of slash-and-burn practices in very poor countries where they can be more serious. Slash-and-burn involves no fertiliser and no synthetic pesticides and can thus be described as organic in character. Africa, for example, has a number of areas where inadequate soil levels of minerals lead to poor crop yields. In turn the low yields leave inadequate plant material to return minerals to the soil particularly when animal manure is used for other purposes, such as cooking fuel.

9. Maeder et al. (2002b) also state that Drinkwater et al. (1998) reported that organic yields can be the same as conventional yields. The actual yields obtained by Drinkwater et al. (1998) over a whole 10 year period were about half that of conventional farming as pointed out by Sinclair and Cassman (1999). To get yields the same would currently have required a number of years of leys with the legume ploughed in every year. In the UK this is unlikely but in the warmer parts of the USA two crops/year might well be feasible. If several leys are ploughed in, extensive nitrate leaching into waterways will be the consequence.

Conventional farming replaced organic farming because the limitations of organic agriculture were only too apparent. That is not to say that conventional farming cannot be improved, it most certainly can, but the way forward is to improve what is already there. In my view improving managerial ability is the best advance that can be made. Incorporating the good points of organic agriculture (insistence on longer rotations, high standards on animal welfare and an inspection system for example) is clearly a better way forward but combined with a flexibility in approach with the goal of environmental improvement but most efficient use of land. Excess land can then be used for other useful purposes such as forest.

I have used the Maeder et al. (2002a) paper to encapsulate what seem to me to be the limitations and faults of current ideologically committed organic attitudes. Exaggeration of problems, use of generalities to cover what are often less-than-serious problems, biased assumptions and statements made without necessary rigour about conventional farming and finally being 30–40 years out of date, failing to recognise the improvements that have taken place in the lost 40 years.

10. Conclusions

In comparison with poorly managed conventional farms, organic will always look better. But times have changed and management has gradually improved, the result of specialist advice from government regulation and agronomy alike. There is no basis for the assertions of the superiority of organic farming once management is taken into account. The standards of agricultural management are a theme which has come through this survey again and again. However managers need training in assessing their farm as a system so that they can appreciate how many of the changes, introduced by IFM farmers, can improve the actual yield and thus economic return at the farm gate as well as providing high quality produce. Diversity of crops within a farm can improve income by lowering yearly variations in income resulting from price variation and weather, much as diverse investment portfolios can help stabilise financial return. Cultivating multiple crops, inter-cropping, growing mixed varieties of the same genotype for animal feed if nothing else can reduce disease and pest problems (Wolfe, 1985). All these are managerial issues that result from viewing the farm properly as an inter-linked system (Fig. 1). But crucially no-till currently appears as superior to other forms of conventional management. No-till is a managerial choice and organic opposition to GM crops to prevent adjacent farmers using GM no-till may reflect recognition of how powerful a competitor to organic farming it actually is. The key to improving UK agriculture is to raise the general standard of farmer managerial competence.

Every technology has its problems because none almost by definition will ever be perfect (Goklany and Trewavas, 2003). But to throw away technology because some problems emerge, denies the potential value of improvements. Organic agriculture is simply another form of farming with its own problems as illustrated in this article. What ever problems countries have with agriculture, world wide cereal yields have continued to rise unchecked (Dyson, 1996). Whether these will provide sufficient food for a continuing rise in population only the future can tell.

If it is thought desirable that a variety of farming should take place in any country then there may be a case for organic just as there is for conventional with good practice and for integrated and for integrated no-till. But the health benefits from low prices of fruit and vegetables are crucial. If the environment is the issue then present data suggests that no-till is better. However, most of the data on no-till comes from the USA and there has only been limited amounts of research to test these possibilities in the UK.

If it is thought that we overproduce food in Europe then several possibilities suggest themselves. Either food can be donated as part of overseas aid but sold by the receiver governments at market prices who then keep the difference as aid for other projects including the provision of machinery, fertilisers and pesticides. Alternatively as English Nature has recently and sensibly done, purchase farmland and turn it back to fenland, except that I would welcome the return of deciduous forests, not from land which is currently used for spruce forests but from our supposed excess.

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