ISIS Press Release 31/1/08

Mitigating Climate Change through Organic Agriculture and Localized Food Systems

*Organic, sustainable agriculture that localize food systems has the potential to mitigate nearly thirty percent of global greenhouse gas emissions and save one-sixth of global energy use***.** Dr. Mae-Wan Ho *and* ***Lim Li Ching***

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Modern industrial agriculture of the "Green Revolution" contributes a great deal to climate change. It is the main source of the potent greenhouse gases nitrous oxide and methane; it is heavily dependent on the use of fossil fuels, and contributes to the loss of soil carbon to the atmosphere [1] (Feeding the World under Climate Change, *SiS* 24), especially through deforestation to make more land available for crops and plantations. Deforestation is predicted to accelerate as bio-energy crops are competing for land with food crops [2] (Biofuels: Biodevastation, Hunger & False Carbon Credits, *SiS* 33). But what makes our food system really unsustainable is the predominance of the globalised commodity trade that has resulted in the integration of the food supply chain and its concentration in the hands of a few transnational corporations. This greatly increases the carbon footprint and energy intensity of our food consumption, and at tremendous social and other environmental costs. A UK government report on food miles estimated the direct social, environmental, and economic costs of food transport at over £9 billion each year, which is 34 percent of the £26.2 billion food and drinks market in the UK [3] (Food Miles and Sustainability, *SiS* 28).

Consequently, there is much scope for mitigating climate change and reversing the damages through making agriculture and the food system as a whole sustainable, and this is corroborated by substantial scientific and empirical evidence (see below). It is therefore rather astonishing that the Intergovernmental Panel on Climate Change should fail to mention organic agriculture as a means of mitigating climate change in its latest 2007 report [4]; nor does it mention localising food systems and reducing long distance food transport [5].

Reducing direct and indirect energy use in agriculture

There is no doubt that organic, sustainable agricultural practices can provide synergistic benefits that include mitigating climate change. As stated in the 2002 report of the United Nations Food and Agriculture Organisation (FAO), organic agriculture enables ecosystems to better adjust to the effects of climate change and has major potential for reducing agricultural greenhouse gas emissions [6].

The FAO report found that, “Organic agriculture performs better than conventional agriculture on a per hectare scale, both with respect to direct energy consumption (fuel and oil) and indirect consumption (synthetic fertilizers and pesticides)”, with high efficiency of energy use.

Since 1999, the Rodale Institute’s long-term trials in the United States have reported that energy use in the conventional system was 200 percent higher than in either of two organic systems - one with animal manure and green manure, the other with green manure only - with very little differences in yields [7]. Research in Finland showed that while organic farming used more machine hours than conventional farming, total energy consumption was still lowest in organic systems [8]; that was because in conventional systems, more than half of total energy consumed in rye production was spent on the manufacture of pesticides.

Organic agriculture was more energy efficient than conventional agriculture in apple production systems [9, 10]. Studies in Denmark compared organic and conventional farming for milk and barley grain production [11]. The energy used per kilogram of milk produced was lower in the organic than in the conventional dairy farm, and it also took 35 percent less energy to grow a hectare of organic spring barley than conventional spring barley. However, organic yield was lower, so energy used per kg barley was only marginally less for the organic than for the conventional.

The total energy used in agriculture accounts for about 2.7 percent of UK’s national energy use [12], and about 1.8 percent of national greenhouse gas emissions [13] based on figures for 2002, the latest year for which estimates are available. Most of the energy input (76.2 percent) is indirect, and comes from the energy spent to manufacture and transport fertilizers, pesticides, farm machinery, animal feed and drugs. The remaining 23.8 percent is used directly on the farm for driving tractors and combine harvesters, crop drying, heating and lighting glasshouses, heating and ventilating factory farms for pigs and chickens. Nitrogen fertiliser is the single most energy intensive input, accounting for 53.7 percent of the total energy use. Thus, phasing out nitrogen fertilizer will save 1.5 percent of national energy use and one percent of national ghg emissions, not counting the nitrous oxide from N fertilizers applied to the fields (see below). Globally, the savings in fossil energy use and ghg emissions could easily be double these figures.

It takes 35.3 MJ of energy on average to produce each kg of N in fertilizers [14]. UK farmers use about 1 million tonnes of N fertilisers each year. Organic farming is more energy efficient mainly because it does not use chemical fertilizers [15].

The Soil Association found that organic farming in the UK is overall about 26 percent more efficient in energy use per tonne of produce than conventional farming, excluding tomatoes grown in heated greenhouses [15]. The savings differ for different crops and sectors, being the greatest in the milk and beef, which use respectively 28 and 41 percent less energy than their conventional counterparts.

Amid rapidly rising oil prices in 2006, with farmers across the country deeply worried over the consequent increase in their production costs, David Pimentel at Cornell University, New York, in the United States returned to his favourite theme [16]: organic agriculture can reduce farmers’ dependence on energy and increase the efficiency of energy use per unit of production, basing his analysis on new data.

On farms throughout the developed world, considerable fossil energy is invested in agricultural production. On average in the US, about 2 units of fossil fuel energy is invested to harvest a unit of energy in crop. That means the US uses more than twice the amount of fossil energy than the solar energy captured by all the plants, which is ultimately why its agriculture cannot possibly sustain anything like the biofuel production promoted by George W. Bush [17] (Biofuels for Oil Addicts, *SiS* 30).

Corn is a high-yield crop and delivers more kilocalories of energy in the harvested grain per kilocalorie of fossil energy invested than any other major crop [16]. `

Counting all energy inputs in fossil fuel equivalents in an organic corn system, the output over input ratio was 5.79 (i.e., you get 5.79 units of corn energy for every unit of energy you spent), compared to 3.99 in the conventional system. The organic system collected 180 percent more solar energy than the conventional. There was also a total energy input reduction of 31 percent, or 64 gallons fossil fuel saving per hectare. If 10 percent of all US corn were grown organically, the nation would save approximately 200 million gallons of oil equivalents.

Organic soybean yielded 3.84 kilocalories of food energy per kilo of fossil energy invested, compared to 3.19 in the conventional system and the energy input was 17 percent lower. Organic beef grass-fed system required 50 percent less fossil fuel energy than conventional grain-fed beef.

Lower greenhouse gas emissions

Globally, agriculture is estimated to contribute directly 11 percent to total greenhouse gas emissions (2005 figures from Intergovernmental Panel on Climate Change) [18]. The total emissions were 6.1Gt CO_2e, made up almost entirely of CH_4 (3.3 Gt) and N_2O (2.8Gt). The contributions will differ from one country to another, especially between countries in the industrial North compared with countries whose economies are predominantly agricultural.

In the United States, agriculture contributes 7.4 percent of the national greenhouse gas emissions [19]. Livestock enteric fermentation and manure management account for 21 percent and 8 percent respectively of the national methane emissions. Agricultural soil management, such as fertilizer application and other cropping practices, accounts for 78 percent of the nitrous oxide emitted.

In the UK, agriculture is estimated to contribute directly 7.4 percent to the nation's greenhouse gas emissions, with fertilizer manufacture contributing a further 1 percent [20], and is comprised entirely of methane at 37.5 percent of national total [21] and nitrous oxide at around 95 percent of the national total [22]. Enteric fermentation is responsible for 86 percent of the methane contribution from agriculture, the rest from manure; while nitrous oxide emissions are dominated by synthetic fertilizer application (28 percent) and leaching of fertilizer nitrogen and applied animal manures to ground and surface water (27 percent) [23].

Assuming half of all nitrous oxide emissions come from N fertilizers, phasing them out would save 11.56 Mt of CO_2e. This is equivalent to another 1.5 percent of the national ghg emissions. The total ghg savings from phasing out N fertilizers amount to 2.5 percent of UK's national emissions. The UK is not a prolific user of N fertilizers compared to other countries, so globally, it seems reasonable to estimate that phasing out N fertilizers could save at least 5 percent of the world's ghg emissions. This is consistent with earlier predictions.

The FAO had already estimated that organic agriculture is likely to emit less nitrous oxide (N_2O) [6]. This is due to lower N inputs, less N from organic manure from lower livestock densities; higher C/N ratios of applied organic manure giving less readily available mineral N in the soil as a source of denitrification; and efficient uptake of mobile N in soils by using cover crops.

Greenhouse gas emissions were calculated to be 48-66 percent lower per hectare in organic farming systems in Europe [24], and were attributed to no input of chemical N fertilizers, less use of high energy consuming feedstuffs, low input of P, K mineral fertilizers, and elimination of pesticides, as characteristic of organic agriculture.

Many experiments have found reduced leaching of nitrates from organic soils into ground and surface waters, which are a major source of nitrous oxide (see above). A study reported in 2006 also found reduced emissions of nitrous oxide from soils after fertilizer application in the fall, and more active denitrifying in organic soils, which turns nitrates into benign N_2 instead of nitrous oxide and other nitrogen oxides [25] (see Cleaner Healthier Environment for All, *SiS* 37).

It is also possible that moving away from a grain-fed to a predominantly grass-fed organic diet may reduce the level of methane generated, although this has yet to be empirically tested. Mike Abberton, a scientist at the Institute of Grassland and Environmental Research in Aberystwyth, has pointed to rye grass bred to have high sugar levels, white clover and birdsfoot trefoil as alternative diets for livestock that could reduce the quantity of methane produced [26].

A study in New Zealand had suggested that methane output of sheep on the changed diet could be 50 percent lower. The small UK study did not achieve this level of reduction, but found nevertheless that "significant quantities" of methane could be prevented from getting into the atmosphere. Growing clover and birdfoot trefoil could help naturally fix nitrogen in organic soil as well as reduce livestock methane.

Greater carbon sequestration

Soils are an important sink for atmospheric CO_2, but this sink has been increasingly depleted by conventional agricultural land use, and especially by turning tropical forests into agricultural land. The Stern Review on the Economics of Climate Change commissioned by the UK Treasury and published in 2007 [27] highlights the fact that 18 percent of the global greenhouse gas emissions (2000 estimate) comes from deforestation, and that putting a stop to deforestation is by far the most cost-effective way to mitigate climate change, for as little as $1/ t CO_2 [28] (see The Economics of Climate Change, *SiS* 33). There is also much scope for converting existing plantations to sustainable agroforestry and to encourage the best harvesting practices and multiple uses of forest plantations [29, 30] (Multiple Uses of Forests, Sustainable Multi-cultures for Asia & Europe, SiS 26)

Sustainable agriculture helps to counteract climate change by restoring soil organic matter content as well as reducing soil erosion and improving soil physical structure. Organic soils also have better water-holding capacity, which explains why organic production is much more resistant to climate extremes such as droughts and floods [31] (Organic Agriculture

Enters Mainstream, Organic Yields on Par with Conventional & Ahead during Drought Years, *SiS* 28), and water conservation and management through agriculture will be an increasingly important part of mitigating climate change.

The evidence for increased carbon sequestration in organic soils seems clear. Organic matter is restored through the addition of manures, compost, mulches and cover crops.

The Sustainable Agriculture Farming Systems (SAFS) Project at University of California Davis in the United States [32] found that organic carbon content of the soil increased in both organic and low-input systems compared with conventional systems, with larger pools of stored nutrients. Similarly, a study of 20 commercial farms in California found that organic fields had 28 percent more organic carbon [33]. This was also true in the Rodale Institute trials, where soil carbon levels had increased in the two organic systems after 15 years, but not in the conventional system [34]. After 22 years, the organic farming systems averaged 30 percent higher in organic matter in the soil than the conventional systems [31].

In the longest running agricultural trials on record of more than 160 years, the Broadbalk experiment at Rothamsted Experimental Station, manure-fertilized farming systems were compared with chemical-fertilized farming systems [35]. The manure fertilized systems of oat and forage maize consistently out yielded all the chemically fertilized systems. Soil organic carbon showed an impressive increase from a baseline of just over 0.1 percent N (a marker for organic carbon) at the start of the experiment in 1843 to more than double at 0.28 percent in 2000; whereas those in the unfertilized or chemical-fertilized plots had hardly changed in the same period. There was also more than double the microbial biomass in the manure-fertilized soil compared with the chemical-fertilized soils.

It is estimated that up to 4 tonnes CO_2 could be sequestered per hectare of organic soils each year [36]. On this basis, a fully organic UK could save 68 Mt of CO_2 or 10.35 percent of its ghg emissions each year. Similarly, if the United States were to convert all its 65 million hectares of crop lands to organic, it would save 260 Mt CO_2 a year [37]. Globally, with 1.5335 billion hectares of crop land [38] fully organic, an estimated 6.134 Gt of CO_2 could be sequestered each year, equivalent to more than 11 percent of the global emissions, or the entire share due to agriculture.

As Pimentel stated [16]: "..high level of soil organic matter in organic systems is directly related to the high energy efficiencies observed in organic farming systems; organic matter improves water infiltration and thus reduces soil erosion from surface runoff, and it also diversifies soil-food webs and helps cycle more nitrogen from biological sources within the soil."

Reducing energy and greenhouse gas emissions in localised sustainable food systems

Agriculture accounts only for a small fraction of the energy consumption and greenhouse gas emissions of the entire food system.

Pimentel [16] estimated that the US food system uses about 19 percent of the nation's total fossil fuel energy, 7 percent for farm production, 7 percent for processing and packaging and 5 percent for distribution and preparation. This is already an underestimate, as it does not include energy embodied in buildings and infrastructure, energy in food wasted, nor in treating food wastes and processing and packaging waste, which would be necessary in a full life cycle accounting.

Similarly, when the emissions from the transport, distribution, storage, and processing of food are added on, the UK food system is responsible for at least 18.4 percent of the national greenhouse gas emissions [39], again, not counting buildings and infrastructure involved in food distribution, nor wastes and waste treatments.

Here’s an estimate of the greenhouse gas emissions from eating based on a full life cycle accounting, from farm to plate to waste, from data supplied by CITEPA (Centre Interprofessionnel Technique d’Eudes de la Pollution Atmosphérique) for France [37].

Greenhouse gas emissions from eating (France)

Agriculture direct emissions	42.0 Mt C
Fertilizers (French fertilizer industry only, more than half imported.)	0.8 Mt C
Road transport goods (within France only, not counting export/import)	4.0 Mt C
Road transport people	1.0 Mt C
Truck manufacture & diesel	0.8 Mt C
Store heating (20% national total)	0.4 Mt C
Electricity (nuclear energy in France, multiply by 5 elsewhere)	0.7 Mt C
Packaging	1.5 Mt C
End of life of packaging (overall emissions of waste 4 Mt)	1.0 Mt C
Total	52.0 Mt C
National French emission	171.0 MtC
Share linked to food system	30.4%

The figure of 30.4 percent is still an underestimate, because it leaves out emissions from the fertilizers imported, from pesticides, and transport associated with import/export of food. Also, the emission of electricity from *established* nuclear power stations in France is one-fifth of typical non-nuclear sources. Others may argue that one needs to include infrastructure costs, so that buildings and roads, as well as the building of nuclear power stations need to be accounted for.

On the most conservative estimates based on these examples, localising food systems could save at least 10 percent of CO_2 emissions and 10 percent of energy use globally.

The tale of a bottle of ketchup

It is estimated that food manufacturing is responsible for 2.2 percent and packaging for 0.9 percent of UK’s ghg emissions [20], while in the US, 7 percent of the nation’s energy use goes into food processing and packaging.

A hint of how food processing and packaging contribute to the energy and greenhouse gas budgets of the food system can be gleaned by the life-cycle analysis of a typical bottle of ketchup.

The Swedish Institute for Food and Biotechnology did a life-cycle analysis of tomato ketchup, to work out the energy efficiency and impacts, including the environmental effects of global warming, ozone depletion, acidification, eutrophication, photo-oxidant formation, human toxicity and ecotoxicity [41].

The product studied is one of the most common brands of tomato ketchup sold in Sweden, marketed in 1 kg red plastic bottles. Tomato is cultivated and processed into tomato paste in Italy, packaged and transported to Sweden with other ingredients to make tomato ketchup.

The aseptic bags used to package the tomato paste were produced in the Netherlands and transported to Italy; the bagged tomato paste was placed in steel barrels, and moved to Sweden. The five-layered red bottles were either made in the UK or Sweden with materials from Japan, Italy, Belgium, the USA and Denmark. The polypropylene screw cap of the bottle and plug were produced in Denmark and transported to Sweden. Additional low-density polyethylene shrink-film and corrugated cardboard were used to distribute the final product. Other ingredients such as sugar, vinegar, spices and salt were also imported. The bottled product was then shipped through the wholesale retail chain to shops, and bought by households, where it is stored refrigerated from one month to a year. The disposal of waste package, and the treatment of wastewater for the production of ketchup and sugar solution (from beet sugar) were also included in the accounting.

The accounting of the whole system was split up into six subsystems: agriculture, processing, packaging, transport, shopping and household.

There are still many things left out, so the accounting is nowhere near complete: the production of capital goods (machinery and building), the production of citric acid, the wholesale dealer, transport from wholesaler to the retailer, and the retailer. Likewise, for the plastic bottle, ingredients such as adhesive, ethylenevinylalcohol, pigment, labels, glue and ink were omitted. For the household, leakage of refrigerants was left out. In agriculture, the assimilation of carbon dioxide by the crops was not taken into consideration, neither was leakage of nutrients and gas emissions such as ammonia and nitrous oxide from the fields. No account was taken of pesticides.

We estimated the energy use and carbon emissions for each of the six subsystems from the diagrams provided in the research paper, and have taken the energy content of tomato ketchup from another brand to present their data in another way (Tables 1 and 2), taking the minimum values of energy and emissions costs.

Table 1. Energy Accounting for 1 kg Tomato Ketchup

Subsystem	Energy GJ
Agriculture	1.3
Processing	7.2

Packaging	7.8 (without waste incineration)
	6.0 (with waste incineration)
Transport	1.0
Shopping	1.2
Household	1.4 (refrigeration for one month)
	14.8 (refrigeration for one year)
Total (minimum)	**18.1**
Energy in 1 kg tomato paste	0.00432
Energy use per GJ tomato paste	**4 190**

Table 2. Carbon Dioxide Accounting for 1 kg Tomato Ketchup

Subsystem	Carbon dioxide equivalent kg
Agriculture	190
Processing	500
Packaging	1 275 (without incineration)
	2 315 (with incineration)
Transport	130
Shopping	195
Household	0
Total (minimum)	**2 290**

As can be seen, it takes at least 4190 units of energy to deliver 1 unit of ketchup energy to our dinner table, with at least 2 290 kg of carbon dioxide emissions per kg ketchup.

Packaging and food processing were the hotspots for many impacts. But at least part of the packaging is due to the necessity for long distance transport. Within the household, the length of time stored in the refrigerator was critical.

For eutrophication, the agricultural system is an obvious hotspot. For nitrous oxide emissions, transportation is another hotspot. For toxicity, the agriculture, food processing and packaging were hotspots, due to emissions of sulphur dioxide, nitrogen oxides and carbon monoxide; also heavy metals, phenol or crude oil. If leakage of pesticides, their intermediates and breakdown products had been considered, then agriculture would have been an even worse toxicological hotspot.

As regards the capital costs for tomato cultivation omitted from the study, literature from France gave a value of 0.180GJ/kg. As regards the wholesale and retail step left out of the study, literature data indicate 0.00143GJ/kg beer for storage at wholesale trader in Switzerland and 0.00166GJ/kg bread in the Netherlands.

There is clearly a lot of scope in reducing transport, processing and packaging, as well as storage in our food system, all of which argue strongly in favour of food production for local consumption in addition to adopting organic, sustainable agricultural practices. An integrated organic food and energy farm that turns wastes into resources can be the ideal solution to reducing greenhouse gas emissions at source, decreasing environmental pollution, reducing transport, and increasing energy efficiencies to the point of not having to use fossil fuels altogether [42] (Dream Farm 2, Organic, Sustainable, Fossil Fuel Free, In Food Futures Now, ISIS Publication).

Assuming that it is feasible to reduce the energy consumption and carbon emissions by 50 percent, at least partly due to localising food systems, this could save 3.5 percent of global energy use and 1.5 percent of global ghg emissions.

Total mitigating potential of organic sustainable food systems

The preliminary estimates of the potential of organic sustainable food systems to mitigate climate change based on work reviewed in this Chapter are presented in Box 2.

Box 2 Global potential of organic sustainable food systems for mitigating climate change

Greenhouse gas emissions	
Carbon sequestration in organic soil	11.0 %
Localising food systems	
Reduced transport	10.0%
Reduced processing & packaging	1.5 %
Phasing out N fertilizers	
Reduced nitrous oxide emissions	5.0 %
No fossil fuels used in manufacture	2.0 %
Total	**29.5 %**
Energy	
Localising food system	
Reduced transport	10.0 %
Reduced processing & packaging	3.5 %
Phasing out N fertilizers	
No fossil fuels used	3.0 %
Total	**16.5 %**

The total mitigating potential of organic sustainable food systems is 29.5 percent of global ghg emissions and 16.5 percent of energy use, the largest components coming from carbon sequestration and reduced transport from relocalising food systems.

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