

Food Futures Now

ISIS TWN



Mae-Wan Ho

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**Organic *Sustainable *Fossil Fuel Free*

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Dedicated to

Edward Goldsmith

Author of *The Blueprint for Survival*, and Founding Editor of *The Ecologist*, who got (almost) everything right for saving the world well ahead of everyone else



Institute of Science in Society

TWN

Third World Network

Foreword

Chemical-based agriculture has been failing over the past three decades, exacting a terrible toll on soil, water, biodiversity, food security, human health and climate. It demands change on a global scale. For this to happen, we need to draw on farmers' experience and local knowledge that has been marginalized and displaced by the Green Revolution, and we need the appropriate science that can work synergistically with local knowledge. The challenges of feeding the planet can only be met by bringing together diverse knowledge systems and experiences rooted in understanding and respecting the complexities of nature and cultures. When that happens, the world shifts from despair to hope.

This book brings together all the necessary ingredients for a scientific evaluation and affirmation of diverse localised food and energy systems that put people at the centre stage. It is a refreshing liberation from the hollow promises of new biotechnologies that serve only corporate interests, and often to suppress honest and truly innovative thinking in the scientific community.

Everyday life-story and scientific narrative flow easily from one to the other and back, reflecting the inseparable ecological, social and economic strands that need to be woven together at every stage in our common goal of harvesting food for today and to-morrow.

We in Third World Network have had the privilege of sharing the exciting journey started in Tigray, Ethiopia, when scientists and local communities joined forces to show their country and the world how composting and simple water conservation techniques can work wonders. Soil fertility is rapidly restored, and crop yields increase by more than 30 percent compared to chemical fertilisers, as documented by data collected over seven years.

Our partners in many countries have participated in similar community projects and witnessed comparable successes, and some of their stories too, are told in this book. It is time for these experiences to spread, and to be recognised by governments and global institutions. It is time for national and international policies to mainstream organic, ecological agriculture, and for resources to be committed to support food and energy systems that make the future truly sustainable.

Chee Yokeling

March 2008

Preface

Warming of the climate system is unequivocal, and it is accelerating, says the latest Intergovernmental Panel on Climate Change (IPCC) Report, released 17 November 2007. Eleven of the past twelve years are among the warmest since records began. Sea levels are rising faster than predicted. Heavy rains, droughts and heat waves are more frequent, and happening over larger areas of the globe. An "increase in intense tropical cyclone activity" was dramatically enacted by Cyclone Sidr, which hit Bangladesh two days earlier, leaving a death toll of more than 10 000 and rising, and an estimated 900 000 families affected.

It will be considerably worse as the century progresses, IPCC predicts, and has "very high confidence" that human activities are to blame, most of all, in burning fossil fuels. The annual growth rate of CO₂ in the atmosphere has jumped from an average of 1.4 ppm a year since 1960 to 1.9 ppm over the past ten years.

The good news is we can do a lot to mitigate global warming by reducing greenhouse gas emissions. IPCC tells us that fighting global warming to keep CO₂ levels down to the most stringent levels will cost less than 0.16 percent of Global GDP a year up to 2030. Needless to say, not doing anything will cost many, many times more, if not the earth itself. Surprisingly, however, IPCC has failed to mention organic agriculture or sustainable food systems in mitigating climate change.

That is why *Food Futures Now* is so timely. It documents the enormous potential for reducing greenhouse gas emissions - even to the extent of freeing us entirely from fossil fuels - through organic, sustainable agriculture and localised food (and energy) systems that put farmers' rights and self-sufficiency of local communities before trade. *Food Futures Now* is a unique combination of the latest scientific analyses, case studies on farmer-led research, and especially farmers' own experiences and innovations that often confound academic scientists wedded to outmoded and obsolete theories. There is a welcome mix of practical know-how and theoretical concepts to put things in the broadest perspective.

This volume is the second report of ISIS' "Sustainable World Initiative", launched April 2005, to "make our food system sustainable, ameliorate climate change and guarantee food security for all." The first report, *Which Energy?* [1], was produced in 2006 when it became clear that sustainable energy use is also a key issue as fossil energies are depleting, and demand for unsustainable "biofuels" is threatening food security and accelerating climate change. In that report, we made 18 recommendations for a mixture of renewable energy options at the medium, small, and micro-generation levels, including biogas from anaerobic digestion of biological wastes, solar and wind power. We ruled out nuclear energy, any energy-intensive extraction of fossil fuels or carbon capture and storage process that extends our dependence on fossil fuels, and energy crops for biofuels (unless they are shown to be truly sustainable).

We also recommended organic, low input sustainable farming for mitigating climate change, especially integrated food and energy production, with emphasis on the use of local resources, and consumption at the point of production.

The present volume is an extended, in-depth argument for this option, touching on the transformation of the dominant knowledge system it entails.

I hope everyone will read it, policy-makers and citizens alike, scientists, farmers and the general public. *Food Futures Now* is a manual for social revolution to a post-fossil fuel economy: how to survive climate change, and better yet, to restore the good life to all.

Mae-Wan Ho
March 2008

Authorship and Acknowledgments

Sam Burcher has written Chapters 9, 21, 23, and 28. Chapters 4, 14 and 15 are by Rhea Gala, formerly researcher with ISIS. Chapter 11 is by Sue Edwards, Director of the Institute of Sustainable Development, Addis Ababa, Ethiopia, with statistical analyses of the data by Prof. Peter Saunders of ISIS and Prof. Emeritus of Mathematics, King's College, London University. Chapter 3 is by Martin Khor, Director of Third World Network. Chapter 18 is by Lim Li Ching, Dr. Mae-Wan Ho and Prof. Joe Cummins. (Lim Li Ching, formerly researcher with ISIS and Deputy Editor of *Science in Society*, is now researcher with Third World Network. Prof. Joe Cummins is ISIS Distinguished Fellow and Emeritus Professor of Plant Genetics, University of Western Ontario, Canada.) Chapter 22 is by Lim Li Ching and Dr. Mae-Wan Ho; Chapters 19, and 25 by Dr. Mae-Wan Ho and Lim Li Ching. Chapter 20 is by Dr. Mae-Wan Ho, Dr. Eva Novotny, Prof. Joe Cummins, Prof. Peter Saunders and Lim Li Ching. (Dr. Eva Novotny is Special Associate of ISIS.) Chapter 29 is by Toby Risk, independent researcher. Chapter 31 is by Prof. Bob Ørskov OBE, head of International Feed Resource Unit, Macaulay Institute, Aberdeen, Scotland, Fellow of the Royal Society of Edinburgh & Fellow of the Polish Academy of Science.

Dr. Mae-Wan Ho has written all other chapters and also edited the entire volume.

Andy Watton is responsible for design and production, Sam Burcher for publication, print and distribution, liaising with sponsors and is a main organiser of the Independent Science Panel and Sustainable World events, and Julian Haffegge for other support.

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Challenges

- 1 -

Why We Need Organic Sustainable Food Systems Now

A global shift to sustainable food systems is urgently needed if we are to survive global warming, failing harvests, falling water tables and fossil fuels shortage

Sustainable food systems offer many synergistic benefits for tackling climate change, improving health and the environment and reducing poverty and inequality



Current food production system collapsing

World grain yields fell for six of the past seven years [1], bringing reserves to the lowest since the early 1980s [2]. In too many food production regions of the world, conventional farming practices have severely depleted the underground water to the point where rivers and lakes have dried out, topsoil has been eroded away, and wild life decimated [3]. At the same time, world oil production may have passed its peak [4], with the peak of natural gas production not far behind [5]. A report released in October 2007 by the German Energy Watch Group presented evidence based on actual production data that world oil production has indeed peaked in 2006 [6]. Conventional industrial agriculture is heavily dependent on both fossil fuels as well as water. The true costs of our current food production system are becoming all too clear, especially when we factor in the social impacts of the global food trade and the systematic subsidized dumping of agricultural surpluses on poor Third World countries (see Box 1.1).

Box 1.1

True costs of the industrial food production system

- 1 000 tonnes of water are consumed to produce one tonne of grain [7]
- 10-15 energy units are spent for every energy unit of food on our dinner table [8, 9]
- More than 1 000 energy units are used for every energy unit of processed food [10]
- 17 percent of the total energy use in the United States goes into food production and distribution, accounting for more than 20 percent of all transport within the country; this excludes energy used in import and export [11]
- 12.5 energy units are wasted for every energy unit of food transported per thousand air-miles [12, 13]
- Current EU and WTO agricultural policies maximise food miles resulting in scandalous "food swaps" [14, 15]
- About 20 percent of greenhouse gas emissions come from agriculture, not including forest conversion and burning biomass, it produces 60 percent of CH₄ and 70 percent of N₂O [16]
- A life cycle accounting shows that the French food system from farm to dinner plate is responsible for more than 30 percent of national greenhouse gas emissions [17]
- US\$318 billion of taxpayer's money was spent to subsidize agriculture in OECD countries in 2002, while more than 2 billion subsistence farmers in developing countries tried to survive on \$2 a day [18, 19]
- Nearly 90 percent of the agricultural subsidies benefit corporations and big farmers growing food for export; while 500 family farms close down every week in the US [18]
- Subsidized surplus food dumped on developing countries creates poverty, hunger and homelessness on massive scales [18]

Another major factor in the imminent collapse of agricultural production is climate change. There is no doubt that it is happening [20] and happening fast [21]. An international team of scientists analysed data in the recent past and found that crop yields fall by 10 percent for each deg. C rise in night-time temperature during the growing season [22]. But this did not take account of the increasing frequencies of drought and flood that devastate crops and livestock. It is widely accepted that such weather extremes are the result of climate change [23], and the outlook is grim.

The latest 2007 Intergovernmental Panel on Climate Change Report (IPCC) predicts that temperature could rise as high as 6.4 C over this century if current trends continue [24]. The increase in CO₂ in the atmosphere has taken a sharp upward turn from 1.1 percent a year for 1990-1999 to 3.3 percent a year for 2000-2006 [25]. The study from the Global Carbon Project published in October 2007 found that the CO₂ emission re-absorbed by the land and oceans have dropped from about 600 kg per tonne of CO₂ emitted 50 years ago to 550 kg in 2006, with the main reduction of uptake by the oceans. Measurements of the north Atlantic taken by UK scientists over ten years from mid 1990s to 2005 confirmed that the carbon sink especially in the northeast of the area covered has reduced by more than 50 percent in ten years [26]. Other research has even suggested that areas of the ocean has become a carbon source rather than a carbon sink [27], and may well further accelerate climate change through positive feedback.

To make matters worse, the shortfall in fossil fuels production to meet increasing demand has resulted in a global scramble for biofuels. Biofuels such as ethanol and biodiesel compete directly with food for feedstock, such as maize, soybean, oilseed rape, wheat, sugarcane etc., sending food prices sky-high. They also compete for land to grow the crops. Large swathes of tropical rainforests razed to the ground are replaced by oil palm and soybean plantations, releasing extra megatonnes of CO₂ into the atmosphere and further accelerating global warming (see Chapter 5).

Agricultural production is just part of the problem we face, which extends through the entire food system of production, distribution and consumption. Getting our food system sustainable is the most urgent task for humanity; it is also the key to delivering health, mitigating and ameliorating the worst effects of climate change, and saving the planet from destructive exploitation.

Multiple synergistic benefits of sustainable food systems

The benefits of sustainable food systems are increasingly evident (see Box 1.2).

In the rest of this volume, we shall deal with the themes outlined in greater depth. We shall describe the abundant scientific and empirical evidence of how we can avert the collapse of the food system and mitigate climate change by a comprehensive shift to organic agricultural production using a variety of sustainable methods and systems that emphasize self-sufficiency and reciprocity, the maximum use of indigenous agricultural biodiversity, and consumption at the point of production.

Last but not least, we need to transform the dominant economic model and the knowledge system in which it is embedded [49, 50]. Obsolete, discredited theories are a major stumbling block for the widespread implementation of sustainable food systems.

Box 1.2

Some benefits of organic, sustainable food production systems

- 2 to 7-fold energy saving on switching to low-input/organic agriculture [10, 28]
- 5 to 15 percent global fossil fuel emissions offset by sequestration of carbon in organically managed soil [29]
- 5.3 to 7.6 tonnes of carbon dioxide emission disappear with every tonne of nitrogen fertilizer phased out [30]
- Up to 258 tonnes of carbon per hectare can be stored in tropical agro-forests [31], which in addition, sequester 6 tonnes of carbon per hectare per year [32]
- Biogas digesters provide energy and turn agricultural wastes into rich fertilizers for zero-input, zero-emission farms [33]
- 625 thousand tonnes of carbon dioxide emissions prevented each year in Nepal through harvesting biogas from agricultural wastes [34]
- 2- to 3-fold increase in crop yield using compost in Ethiopia, outperforming chemical fertilizers [35]
- Organic farming in the US yields comparable or better than conventional industrial farming [36, 37], especially in times of drought [38]
- Organic farms in Europe support more birds, butterflies, beetles, bats, and wild flowers than conventional farms [39]
- Organic foods contain more vitamins, minerals and other micronutrients, and more antioxidants than conventionally produced foods [40-43]
- Scientists find planting trees by local farmers contribute to pushing back the desert in the Sahel [44]
- Up to 4 t CO₂ sequestered per hectare of organic soils each year [45]
- 1 000 or more community-supported farms across US and Canada bring \$36 m income per year directly to the farms [46]
- £50-78 m go directly into the pocket of farmers trading in some 200 established local farmers' markets in the UK [46]
- Buying food in local farmers' market generates twice as much for the local economy than buying food in supermarket chains [47]
- Money spent with a local supplier is worth four times as much as money spent with non-local supplier [48]

- 2 -

Beware the New "Doubly Green Revolution"

The fake moral crusade to feed the world with genetically modified crops promoted as the second "Doubly Green Revolution" is doing even more damage than the first

The bad genetics involved has failed the test in science and in the real world



Norman Borlaugh receiving US Congressional Medal

Bad genetics kills

James Watson, who shared the 1962 Nobel Prize for the double-helix structure of DNA, came to the UK in October 2007 to promote his new book and autobiography, *Avoid Boring People: Lessons From A Life In Science*. But he sparked outrage among fellow scientists for saying to a newspaper reporter that [1] he was "inherently gloomy about the prospect of Africans" because "all our social policies are based on the fact that their intelligence is the same as ours, whereas all the testing says not really." That was not the first time Watson abused his position to promote what the Federation of American Scientists condemned as "personal prejudices that are racist, vicious and unsupported by science" [2]. On a previous occasion, he suggested that people with low IQ had genes for stupidity, and he would like to prevent them from being born or give them gene therapy [3].

Our political leaders are still being ill advised by famous scientists adhering to the old discredited paradigm

Within a week of his latest transgression, Watson was suspended, and subsequently

resigned, from his post as chancellor of the prestigious Cold Spring Harbour Molecular Biology Laboratory.

Nonetheless, it was precisely such eugenicist, genetic determinist propaganda that Watson had used so effectively in promoting the Human Genome Project in the 1980s. And if anything significant had come out of sequencing the human and other genomes, it was to explode the myth of genetic determinism once and for all [4]. Some of us had been arguing all along that genes and environment are inseparable well before the Human Genome Project was conceived. The surprise is how readily the environment could specifically mark and change genes and genomes to influence later generations. 'The inheritance of acquired characters' is nowhere as evident as in molecular genetics [5]. It is part of the ecological genetics of the 'fluid genome' emerging since the 1980s that has made genetic determinism obsolete [4]. Unfortunately, our political leaders are still being ill advised by famous scientists adhering to the old discredited paradigm.

Another Nobel laureate (Nobel Peace Prize 1970) who should know his genetics better is Norman Borlaug, father of the Green Revolution. The Green Revolution was a reductionist approach to agriculture based on using genetics to breed genetically uniform high yielding varieties (HYVs), which has brought short-term increases in crop yields, but at tremendous environmental and social costs.

Borlaug has persisted in promoting this failed approach, especially in its later incarnation of genetically modified (GM) crops, as made clear in a Nature editorial published in October 2007, "Feeding a hungry world" [6].

Far from suffering disgrace, Borlaug is showered with awards, the most recent being the US Congressional Gold Medal, America's highest civilian honour [7]. At the presentation event, M.S. Swaminathan, father of the Green Revolution in India, gave the keynote address.

India, meanwhile, is caught in a worsening

India, gave the keynote address. India, meanwhile, is caught in a worsening epidemic of farmers' suicide. Its agricultural minister acknowledged in the Indian Parliament that an estimated 100 000 farmers have taken their own lives between 1993 and 2003. The introduction GM crops to the country has escalated the suicides to 16 000 a year (see Chapter 23)

Borlaug is doing a great deal more damage to the world than Watson based on their bad genetics. The difference is that while Watson is now a liability in attracting grants and investments for genomics and related post-human genome endeavours, Borlaug serves as the ideal mouthpiece for the biotech industry's fake moral crusade of feeding the world under the banner of the second, "doubly-green" revolution of genetically modified crops.

Lessons from the Green Revolution

The failures of the Green Revolution are widely acknowledged [8], and even by Swaminathan himself [9], who referred to "a fatigue" of the Green Revolution: a sharp drop in the yield of grain per unit of fertilizer applied as well as a drop in yield. In India, grain yield per unit of fertilizer applied decreased by two-thirds during the Green Revolution years. And the same has happened elsewhere.

Between 1970 and 2000, the annual growth of fertilizer use on Asian rice has been 3 to 40 times the growth of rice yields [8]. In Central Luzon, Philippines, rice yield increased 13 percent during the 1980s, but came at the price of a 21 percent increase in fertilizer use. In the Central Plains, yield went up only 6.5 percent, while fertilizer use rose 24 percent and pesticides jumped by 53 percent. In West Java, a 23 percent yield increase was obtained at the cost of 65 and 69 percent increases in fertilizers and pesticides respectively.

However, it is the absolute drop in yields despite high inputs of fertilizer that finally punctured the Green Revolution bubble. By the 1990s, after dramatic increases in the early stages of the Green Revolution, yields began falling. In Central Luzon, Philippines, rice yields rose steadily during the 1970s, peaked in the early 1980s, and have been dropping gradually since. Similar patterns emerged for rice-wheat systems in India and Nepal.

Where yields were not actually declining, the rate of growth has been slowing rapidly or levelling off, as documented in China, North Korea, Indonesia, Myanmar, the Philippines, Thailand, Pakistan, and Sri Lanka.

Since 2000, yields have fallen further, to the extent that in six out of the past seven years, world grain production has fallen below consumption. And consumption is increasing not as much by growing population as by rising demand for biofuels in recent years [10] (see Chapter 5). As a result, world grain stocks have dropped to the lowest since records began 30 years ago, and food prices have shot up worldwide.

The Green Revolution was an industrial style agriculture that packaged HYVs with fertilizers, pesticides, and irrigation. And given optimum

inputs, these HYVs did indeed increase yields dramatically, especially in the short term. In the longer term, Green Revolution agriculture depleted and degraded the soil, yields fall even as more and more fertilizers are used. Similarly, pests develop resistance to pesticides, and greater amounts have to be applied. Farmers and the general public become increasingly at risk from the toxic effects of pesticides and fertilizers that contaminate ground water.

At the same time, heavy irrigation resulted in widespread salination of agricultural land, while aquifers are pumped dry. It is estimated that 6 percent of India's agricultural land has been made useless as a result of salination [8], and nearly a fifth of the sub-continent is withdrawing more water than is being replaced by rain [11]. In the Punjab, home of the Green Revolution, nearly 80 percent of groundwater is now "overexploited or critical."

Instead of learning from the failures of the Green Revolution, Borlaug, Swaminathan, and the biotech industry are offering the world a second "doubly green" revolution in GM crops, taking it to Africa with the help of corporate charities doing more harm than good in the world

The high costs of fertilizer and pesticide put small farmers at a disadvantage right from the start, driving them off the land while big farmers grow bigger, thereby deepening the divide between rich and poor.

But even for those farmers who manage to keep going, the spiralling costs of more fertilizers and pesticides, and diminishing income due to falling yields, or massive crop failures from drought, pests, and diseases, to which the genetically uniform HYVs are especially susceptible, soon plunged farmers deeper and deeper into debt. For many of these farmers, the only exit from debt is suicide. This sorry tale has been told over and over again [12].

It is clear that the Green Revolution's success in raising yields has failed to reduce poverty or hunger. India's 26 million ton grain surplus in 2006 could feed the 320 million hungry people in its population, but starving villagers are too poor to buy the food produced in their own countryside [11].

The Green Revolution also led to the loss of indigenous agricultural biodiversity. This severely compromises food security for small farmers, as the indigenous varieties are more resistant to pest, disease, and drought than the genetically uniform HYVs. Monoculture HYVs also reduce the nutritional value of foods as soils become depleted of essential micronutrients. In Bangladesh, the promotion of Green Revolution rice resulted in a loss of nearly 7 000 traditional rice varieties and many fish species. In the Philippines, more than 300 traditional varieties disappeared.

Instead of learning from the failures of the Green Revolution, Borlaug, Swaminathan, and the biotech industry are offering the world a second "doubly green" revolution [8] in GM crops, and they are taking it to Africa with the help of corporate charities that are doing more harm than good in the world [13].

The Alliance for a Green Revolution in Africa

Bill & Melinda Gates and the Rockefeller Foundation announced a joint \$150 million Alliance for a Green Revolution in Africa (AGRA). The creators of AGRA claim the initiative will bring benefits to the Africa's impoverished farmers who have been bypassed in the first Green Revolution. Bill Gates is a confessed enthusiast for biotechnology [13], while the Rockefeller Foundation is notorious for having invested in creating the 'Golden Rice', genetically modified to produce pro-Vitamin A, and aggressively promoted "to salvage a morally as well as financially bankrupt agricultural biotech industry" [14].

But, as the Food First Institute points out [11], the Consultative Group on International Agricultural Research (CGIAR), which brings together the key Green Revolution research institutions, has invested 40 to 45 percent of their £350 million annual budget in Africa; if not in the Green Revolution, in what? And if in the Green Revolution, it must have failed Africa, and not bypassed it.

Borlaug claims to have reduced world hunger through the Green Revolution, but this too turns out to be a myth

The Green Revolution failed because it did not address the main causes of poverty and hunger, on the contrary it contributed to increasing hunger and poverty in the midst of plenty.

Overcoming poverty and hunger requires the redistribution of land and resources to enable farmers to grow food; they also need a fair and stable market, and ecological farming systems that free farmers from the shackles of expensive inputs of fertilizers and pesticides (see many chapters in this book, especially 22 and 24). This is especially true for sub-Saharan African countries like Ethiopia, Sudan, Somalia and Mali where the area of unused, good quality farmland is many times greater than the area actually farmed. It is also the case in Zimbabwe and South Africa where the majority of farmers have been excluded from

access to minimally acceptable farmland [11].

Borlaug claims to have reduced hunger in the world through the Green Revolution, and many of his critics are willing to give him credit for that. But this too turns out to be a myth.

In the two decades from 1970 to 1990 spanning the Green Revolution, the total food available per person in the world rose by 11 percent while the estimated number of hungry people fell from 942 m to 786 million, a 16 percent drop. However, if China is left aside, the number of hungry people in the rest of the world actually went up by more than 11 percent, from 536 to 597 million.

In South America, while per capita food supplies rose almost 8 percent, the number of hungry people went up by 19 percent. In South Asia, there was 9 percent more food per person by 1990, but there were also 9 percent more hungry people.

In China, the number of hungry dropped dramatically from 406 million to 189 million (a fall of 54.4 percent). As Food First Institute says [8], "[it] almost begs the question: which has been more effective at reducing hunger-the Green Revolution or the Chinese Revolution, where broad-based changes in access to land paved the way for rising living standards?"

The real causes of hunger in Africa

The growing hunger in Africa is largely due to the increased impoverishment of the rural people who once grew food, but have now left farming. Today's African farmers could easily produce far more food than they do, if they can get credit to cover production costs, or find buyers or obtain fair prices to give them a minimum profit margin [11].

Rural Africa has been devastated by 25 years of 'free trade' policies imposed by the World Bank, the International Monetary Fund, the World Trade Organisation, the US and EU [11]. The forced privatisation of food crop marketing boards - which once guaranteed African farmers minimum prices and held food reserves for emergencies - and rural development banks - which gave farmers credit to produce food - left farmers without financing to grow food and without buyers for their produce. Free trade agreements have made it easier for private traders to import subsidized food from the US and EU than to negotiate with thousands of local farmers. This effective dumping drives local farm prices below the costs of production and puts local farmers out of business.

A new technology package with GM crops is not going to make any difference to the social and structural problems, and judging by India's recent experience, it would make things much worse [7]. It will further narrow the genetic base of indigenous agriculture, increase farmers' indebtedness in paying for patented seeds, increase farmers' vulnerability as GM varieties are more susceptible to crop failures, and bring extra environmental and health risks [15]. The "doubly green" revolution can only exacerbate poverty and hunger in Africa

So what does Africa need instead? This has been so obvious it hardly needs saying, as all



forms of sustainable, agro-ecological farming systems around the world, including Africa have been staging a successful revival since the late 1980s [17]. But it is instructive to learn from Cuba's experience, particularly in the light of freeing agriculture from its dependence on fossil fuels (see Chapter 12), which has relevance not just for Africa, but also for all of the rest of the world.

Lessons from Cuba: agriculture without fossil fuels

Cuba is where agriculture without fossil fuels has been put to the test, thanks to the collapse of trade with the former socialist bloc; and it has passed with flying colours [18-20].

Before 1989, Cuba was a model Green Revolution farm economy, based on huge production units, and dependent on vast quantities of imported chemicals and machinery to produce export crops, while over half of its food was imported. The Cuban government's commitment to equity, and favourable terms of trade offered by Eastern Europe, ensured that Cubans were not undernourished [11].

The collapse of the socialist bloc and the tightened US trade embargo exposed the vulnerability of Cuba's Green Revolution model, and it was plunged into the worst food crisis in its history. Cuba lost 85 percent of its trade, including both food and agricultural inputs, and without those inputs, domestic production fell, resulting in a 30 percent reduction in caloric intake in the early 1990s. Cuba was faced with a dual challenge of

doubling food production with half the previous inputs.

In the two decades from 1970 to 1990, the total food available per person in the world rose by 11 percent while the estimated number of hungry people fell from 942 to 786 million, a 16 percent drop. However, if China is left aside, the number of hungry people in the rest of the world actually went up by more than 11 percent, from 536 to 597 million

Yet by 1997, Cubans were eating almost as well as they did before 1989, with little food and agrochemicals imported. Instead, Cuba concentrated on creating a more self-reliant agriculture: a combination of higher crop prices paid to farmers, agro-ecological technology, smaller production units, and urban agriculture.

Cuba's response began with a nation-wide call to increase food production and a restructuring of agriculture. Conventional large-scale, high input monoculture systems were converted to smaller scale, organic and semi-organic farming systems, focussing on using low cost and environmentally safe inputs, and relocating production closer to consumption in order to cut down on transportation. Promoting urban agriculture was a key part of the response, growing food where it is most needed.

A spontaneous, decentralized movement had begun in the cities. People responded enthusiastically to government initiative to grow food. By 1994, more than 8 000 city farms were created in Havana alone. Front lawns of municipal



Child playing with pesticide containers

buildings were dug up to grow vegetables. Offices and schools cultivated their own food. Many of the gardeners were retired men aged 50s and 60s, and urban women played a much larger role in agriculture than their rural counterparts.

By 1998, an estimated 541 000 tons of food were produced in Havana for local consumption. Food quality has also improved as people had access to a greater variety of fresh fruits and vegetables. Urban gardens continued to grow and some neighbourhoods were producing as much as 30 percent of their own food.

The growing hunger in Africa is largely due to the increased impoverishment of the rural people who once grew food, but have now left farming. Today's African farmers could easily produce far more food than they do, if they can get credit to cover production costs, or find buyers or obtain fair prices to give them a minimum profit margin

The rapid growth of urban agriculture owed much to the State's commitment to make unused urban and suburban land and resources available to aspiring urban farmers. Land grants issued in the city converted hundreds of vacant lots into food producing plots, and new planning laws placed the highest land use priority on food production.

Another key to success was opening farmers markets and legalising direct sales from farmers to consumers. Deregulation of prices, combined with high demand for fresh produce in the cities allowed urban farmers to make two to three times as much as the rural professionals.

The government also encouraged gardeners through an extensive support system of extension agents and horticultural groups that offered assistance and advice. Seed houses throughout the city sold seeds, gardening tools, compost and distribute biofertilizers and other biological control agents at low costs.

New biological products and organic gardening techniques were developed by Cuba's agricultural research sector, which had already begun exploring organic alternatives to chemical controls, enabling Cuba's urban farms to become completely organic. A new law prohibited the use of any pesticides for agricultural purposes anywhere within city limits.

Cuba did not invent urban agriculture. It has been a worldwide movement since the 1970s, and by 1999, an estimated 14 percent of the world's food was produced in urban areas. This is perhaps one of the most important aspects of sustainable development, as more and more of the populations worldwide are becoming urbanized. It presents both a challenge and an opportunity for town planning and design to transform the concrete jungle into habitats surrounded by open fields and gardens, which can attract and support wildlife at the same time. Imagine growing up in cities with urban agriculture instead of existing slums and soulless housing estates.

Food Sovereignty for all

Today, across Africa, Latin America and Asia, farmer-to-farmer movements, farmer-led research teams and farmer field schools have already discovered how to raise yields, distribute benefits, protect soils, conserve water and enhance agricultural biodiversity on hundreds of thousands of smallholdings in spite of the Green Revolution [11]. A survey of 45 sustainable agricultural projects/initiatives spread across 17 African countries covering some 730 000 households revealed that agro-ecological approaches substantially improved food production and household food security. In 95 percent of the projects, cereal yields improved by 50 to 100 percent, with additional positive impacts on natural, social and human capital.

The concept of food sovereignty developed by La Via Campesina and brought to the public debate during the World Food Summit in 1996 has gained tremendous popularity and support. It is stated as follows [21]: "Food sovereignty is the right of peoples to define their own food and agriculture; to protect and regulate domestic agricultural production and trade in order to achieve sustainable development objectives; to determine the extent to which they want to be self-reliant; to restrict the dumping of products in their market; and to provide local fisheries-based communities the priority in managing the use of and the rights to aquatic resources. Food Sovereignty does not negate trade, but rather it promotes the formulation of trade policies and practices that serve the rights of peoples to food and to safe, healthy and ecologically sustainable production."

Food sovereignty is opposed to patenting seeds, it also includes agrarian reform, a limit on the maximum farm size, equitable local control over resources such as seeds, land, water, and forests. The food sovereignty approach is increasingly taken seriously by other sectors such as organisations representing consumers, urban poor, indigenous peoples, trade unions, environmentalists and human rights activists, researchers and other experts. It also forms the basis for collaboration between the FAO and farmers groups and other civil society actors, as announced by FAO Secretary General Jacques Diouf at the 2002 World Food Summit. Given appropriate land reform and institutional support in finance and marketing, there is no doubt that farmers in Africa, India and elsewhere can free themselves from the cycle of indebtedness, increasing poverty, hunger, malnutrition and ill-health, especially with zero-input organic farming methods based on indigenous crops and livestock (see Chapter 3). The really green revolution has started in Ethiopia a few years ago, when the government adopted organic agriculture as a national strategy for food security. Crops yields have doubled and tripled while reversing the damages of the failed Green Revolution (see Chapter 11).

- 3 -

Sustainable Agriculture: Critical Ecological, Social & Economic Issues

Major changes in international aid, financial and trade policies are needed if agriculture is to be truly sustainable



Urgent action needed on agriculture

Agriculture is perhaps the most outstanding issue and challenge for sustainability. To attain the goal of sustainable development requires actions on three fronts - the ecological, the social and the economic. There is a looming crisis in this all-important sector that must be promptly addressed, as it impacts on the livelihoods of most of the world's people and everyone else's food needs.

Agriculture faces three major challenges: technology, the global economic framework and land tenure for farmers.

In technology, as the chemical-based Green Revolution model is faltering, the private sector and global establishment are looking to genetic engineering as the way ahead. But all the signs are that ecological farming is superior, not only for the environment, but also for gains in productivity and farmers' incomes (as documented in the many Chapter of this book). Even then, it has not been given the chance to prove its full potential, and it should be.

The global economic environment has turned extremely bad for small farmers in developing countries. The International Monetary Fund (IMF)-

World Bank structural adjustment has put pressure on poor countries to liberalise food imports and abandon subsidies and government marketing boards. The World Trade Organization (WTO) Agreement on Agriculture (AoA) enables rich countries to raise their subsidies and set up astonishingly high tariffs, while punishing developing countries, which cannot increase their subsidies, and are required to liberalise their imports further. Commodity prices have slumped. These three factors are threatening the survival of farms and farmers in developing countries. The entire framework of global and national economic policies for agriculture has to be thoroughly revamped.

The problem of land tenure is especially acute for many small farmers that are poor and some becoming even poorer. A main reason is unequal land distribution, where small farmers have little land security or access and lose a large part of their income to landowners. Land reform is urgently needed and landless farmers are fighting for their rights. But the landowners in most countries have political clout and are resisting change.

All three issues have to be resolved, and in an integrated way if sustainable agriculture is to be realised. Otherwise there will be an absolute catastrophe, especially if the wrong choices are made.

In 1993, the FAO chief for Asia Pacific had already declared the Green Revolution era over

Choice of technology

A review of aid practice is needed to correct past mistakes to lead up to sustainable agriculture and rural development. Important choices have to be made in technology.

Aid for destructive forestry and fishery projects should cease. So too should aid and loans for commercial aquaculture projects that are ecologically and economically unsustainable and harm farmers and fisher folk whose lands and waters are affected. Instead, there should be support for small-scale community-managed and environmentally sound forms of aquaculture aimed at augmenting local food supply, which have been traditionally practised in many countries.

In the past, most agricultural aid has promoted the Green Revolution model, which uses seeds that respond well to large doses of inorganic fertilisers and chemical pesticides. These few seed varieties have displaced a wide range of traditional seeds, greatly eroding crop biodiversity. There is also mounting evidence of decreasing soil fertility, chemical pollution of land and water resources, pesticide poisoning, and pest infestation due to growing pest resistance to pesticides, all symptoms of a technological system in decline (see Chapter 2). The ecological and health hazards should no longer be considered as the necessary costs to an economically and technically superior system, because the system's most important claimed benefit, high productivity, is itself now in question.

In areas where the model has operated for a

longer period, there is evidence of declining yields and rising costs. In 1993, the FAO chief for Asia Pacific had already declared the Green Revolution era over. Trace elements in the soil were increasingly depleted as only major elements can be replaced with fertilisers with intensive cropping, and continued high dependence on pesticides was not technologically sustainable. There was a yield decline of 1 to 3 percent per year in some fields, described as "a recipe for disaster within one generation" by Peter Kenmore, the FAO regional officer for integrated pest control. In International Rice Research Institute (IRRI) test plots, varieties that yielded 10 tonnes per hectare in 1966 were yielding less each year and produced less than 7 tonnes per hectare by the mid-1990s. IRRI scientists attributed the yield decline to environmental degradation from irrigation, which reduced the period when the soil was dry, the substitution of inorganic for organic fertilisers, and a greater uniformity in the varieties grown. These factors are all intrinsic to Green Revolution agriculture.

Disillusionment with the Green Revolution creates the danger that agriculture aid will turn to genetic engineering. Companies, universities and foundations have already pumped enormous funding into biotech research. But the claimed benefits of genetic engineering are far from proven, while there is increasing evidence of real and potential risks as documented in the Independent Science Panel (ISP) report [1]. These scientists have pointed to scientific flaws of the genetic engineering paradigm, showing why it is impossible to predict the consequences of transferring a gene from one organism to another, calling into question the value or usefulness of genetically engineered or genetically modified (GE or GM) crops.

Moreover, genetically modified organisms (GMOs) may migrate, further mutate and multiply, and in some cases the stability of affected organisms and ecosystems could be disrupted and threatened. The more specific risks in agriculture are that some transgenic crops could become noxious weeds, and others could transfer new genes to wild plants, which themselves could then become weeds. The new weeds could adversely affect farm crops and wild ecosystems. Similarly, GM fish, shellfish and insects could become pests under certain conditions. There is also a possibility of new viral strains giving rise to new plant diseases. Of particular concern is the risk that transgenic crops may pose a threat to wild plants and traditional crop varieties and thus accelerate the rapid loss of agricultural biodiversity, especially in developing countries, many of which are world centres of crop origin and diversity.

There is also growing evidence of the hazards to health in consuming food and feed containing GMOs [2]. Consumers around the world are rejecting GM foods [3] and opting for organic produce (see Chapter 7). There should be a moratorium on the environmental releases of GM crops, if not an outright ban as recommended by the Independent Science Panel Report [1].

Meanwhile, ecological agriculture should be

given the chance it deserves. Priority support should be made to research and projects on ecological and community-based farming practices and systems; so far, relatively few resources have been made available.

The value and productivity of Third World traditional agriculture has been underestimated because the wrong estimation methodology have been used in comparing it with the Green Revolution model. This has now been put right. The most comprehensive studies by teams of scientists now show that organic agriculture can indeed feed the world, and especially, the poor of the world (see Chapter 9).

There is a prevailing prejudice that while 'sustainable agriculture' may be good in preserving the environment, it is inferior and inadequate in terms of productivity and thus cannot be relied on to feed increasing populations. This prejudice has been thoroughly exposed (see Chapters 13, 15 and 22). High yields have been obtained under organic management for years. You will come across other specific examples of sustainable, organic agriculture that have doubled and trebled yields in Africa, Asia and Latin America (Chapters 11, 12, 14, 16, 17, 22 and 28) and at least comparable if not higher yields in Europe and the United States (Chapters 13, 15 and 22).

Studies should now be sponsored to understand the many types of low-input ecological farming methods, traditional as well as modern. Such studies should include analyses of their workings; energy efficiency; use of inputs; outputs of all the different crops, products and activities and the relationships between them; and the nature and use of agricultural diversity. The studies should also incorporate the various problems encountered in practice (such as shortage of manure, pest control, water management), and the methods for solving them. (See Chapter 34 for an integrated food and energy farm where many of these studies can be carried out together.)

More specifically, aid should now flow towards the following.

- (a) Reassessing the concept and measurement of agricultural productivity, duly recognising the value of traditional and ecological farming and enabling a scientific comparison with conventional Green Revolution methods.
- (b) Studies on sustainable agriculture systems, their operations and dynamic inter-relationships, problems encountered, and solutions.
- (c) Experiments on sustainable agriculture, test farms and demonstration farms.
Training programmes on sustainable agriculture for farmers, policy and extension officials, and NGOs.
- (d) Support programmes for farmers and government to implement sustainable agriculture, which could eventually take place on a large scale.
- (e) Support for farmers, community groups and governments to establish community-based seed banks in order to revive and promote the use of traditional varieties, exchange of seeds among farmers, and the improvement of seed

varieties using appropriate traditional breeding methods.

- (f) Since the United Nations Conference On Environment And Development (UNCED) in 1992, there has been agreement in principle of the need to move away from environmentally harmful agriculture to sustainable agriculture. While there has been increased interest and awareness of ecological farming, aid agencies and the international agricultural technical agencies have not taken any effective action to phase out chemical-based agriculture nor to promote sustainable agriculture. As consumers worldwide are now opting for organically grown food, this is the time to push forward with ecological, organic agriculture.

We need a large dose of commitment by the aid and loan agencies to move forward and take on board the above recommendations, so that a paradigm shift in policy can take place. The biases against organic ecological agriculture are deep-seated and unjustified; policy-makers are still chasing after new technological miracles to feed the world, whereas the essential elements for both sustainability and productivity already exist in indigenous knowledge and the diversity of Nature's resources, both of which need to be rediscovered and revitalized before they disappear.

Aid for destructive forestry and fishery projects should cease. So too should aid and loans for commercial aquaculture projects that are ecologically and economically unsustainable and harm farmers and fisher folk whose lands and waters are affected

Structural adjustment & the WTO

Globalisation is now the main determining economic factor in Third World agriculture, the major instruments being the Breton Woods institutions (World Bank and IMF) and the WTO. The agriculture component of structural adjustment programmes usually included cutbacks in government expenditure on the agricultural and rural sector; privatisation of state marketing institutions; liberalisation towards private land ownership; liberalisation of agriculture imports; removal or reduction of agricultural subsidies; and the 'freeing' of food and other agricultural prices.

The liberalisation of agricultural imports has had an especially damaging effect on the Third World farm sector, and pressures increased after the establishment of the WTO and especially its AoA (Agreement on Agriculture). Under the AoA, developing countries must remove non-tariff controls on agricultural products and convert these to tariffs, then reduce the tariffs by 24 per cent over 10 years. Cheaper imports are threatening the viability of small farms in many developing countries. Millions of small Third World farmers could be affected. There is also increased fear of greater food insecurity, as developing countries become less self-sufficient in food production. For many, food imports may not be an option due to shortage of foreign exchange. They have to depend on food aid.

A 2000-2001 FAO report on 14 developing

countries implementing the AoA showed that import liberalization has had a significant impact. The average annual value of food imports in 1995-98 exceeded the 1990-94 level in all 14 countries, ranging from 30 per cent in Senegal to 168 per cent in India. The cost of food import more than doubled for two countries (India and Brazil) and increased by 50-100 per cent for another five (Bangladesh, Morocco, Pakistan, Peru and Thailand). In all but two countries, growth in food import exceeded growth in food export. Some countries were obliged to set applied rates well below their WTO bound rates due to loan conditionality. Several countries reported import surges in particular products, notably dairy products (mainly milk powder) and meat. In some regions, especially the Caribbean, import-competing industries faced considerable difficulties.

In Guyana, there were import surges for many main foodstuffs that had been produced domestically in the 1980s under a protective regime. In several instances the surge in imports has undermined domestic production. For example, fruit juices imported from as far away as France and Thailand have now displaced much of domestic production. Producers and traders of beans reported that increasing imports have led to a decline in the production of minca peas, which was developed and spread throughout Guyana in the 1980s. The same fate befell local cabbage and carrot. The fear was expressed that without adequate market protection accompanied by development programmes, many more domestic products would be displaced or sharply undermined, leading to a transformation of domestic diets and to increased dependence on imported foods.

In Sri Lanka, policy reforms and associated increases in food imports have put pressure on some domestic sectors, affecting rural employment. There is clear evidence of an unfavourable impact of imports on domestic output of vegetables, notably onions and potatoes. The resulting decline in the cultivated area of these crops has affected approximately 300 000 involved in their production and marketing.

The rich countries have been notorious for their high protection and subsidy for their own farm sector. The AoA has allowed them to continue high protection through tariffs (some at 100 to 300 per cent) as well as export and domestic subsidy. Indeed, the OECD countries' total domestic farm subsidies rose from US\$275 billion (annual average for 1986-88) to US\$326 billion as an increase in 'non trade distorting subsidy' (allowed under WTO), which more than offset the 'trade distorting subsidy' that has to be reduced under WTO rules. Thus, highly subsidised and artificially cheap food from rich countries are entering the poorer countries that have no funds for subsidies, and put under pressure to further cut their tariffs.

Meanwhile, the WTO's Trade-Related Aspects Of Intellectual Property Rights (TRIPS) Agreement also poses a threat to all farmers, not just those in the South, as governments are required to patent some life-forms, giving intellectual rights protection

to plant varieties. This facilitates 'biopiracy', the appropriation of farmers' knowledge as well as plant genetic resources by companies, and has resulted in a situation where farmers have to prove they did not 'steal' the seeds of protected plant varieties owned by companies, as in the famous case of Canadian farmer Percy Schmeiser who was taken to court by biotech giant Monsanto in 1998 for patent infringement and failure to pay the appropriate technology fee when his fields were contaminated by the company's patented GM canola. [4]. Schmeiser was not alone; Monsanto had made similar charges against hundreds of farmers and small businesses in the United States [5].

The introduction of GM crops into Third World was the last straw for the farmers of countries like India, where massive failures of GM crops have accelerated an epidemic of suicides (see Chapter 24).

What should be done to counteract these problems? I suggest the following.

(a) Structural adjustment conditions must be changed, so that countries can adopt policies that protect the poor and the local farmers. The IMF, World Bank and donor countries should stop putting pressure on developing countries to liberalise their agricultural imports, or to give up subsidies or marketing assistance to farmers.

(b) The AoA must be radically changed. Developing countries should be allowed, under special and differential treatment, to take tariff and non-tariff measures to protect the viability and livelihoods of their small farms. They should be exempt from the disciplines of import liberalisation and subsidy for food products for domestic consumption. Developed countries should not continue to artificially cheapen their products by export subsidies.

(c) The TRIPS Agreement should be amended to prohibit the patenting of life-forms and to enable developing countries to set up their own version of a sui generis system to protect the rights of farmers and indigenous communities as the innovators of plant varieties, without being challenged. (Note added by editor: This is particularly important as Monsanto has lost four patents in less than five months in 2007, thanks to the challenge mounted by the Public Patent Foundation, and this may signal the beginning of the end for patents on GM crops [6]. The patents were all on gene sequences involving the cauliflower mosaic virus promoter that is crucial for getting engineered genes to work. It is in practically all of Monsanto's GM crops grown commercially.)

(d) Developing countries should be allowed the flexibility to establish their own agriculture policies, with the priority of being able to have farmers produce food without being hampered by inappropriate and damaging rules of the IMF, World Bank or WTO.

Access to land & other social issues

Farmers and the rural population in developing countries face serious social problems. As discussed in Chapter 2, first among these is

insecurity of land tenure, and lack of access to land. Many farmers are tenants, beholden to landlords, to whom they pay rent that can significantly reduce the family income. In many countries, unequal land distribution and the exploitation of landless peasants are the major causes of rural poverty and insecurity. Sustainable agriculture and rural development requires a new commitment by governments and international agencies to improve land access and land rights of farmers and indigenous communities. These communities are also affected by development projects, such as dams, forestry and mining, which displace them from their land.

The issue of the human rights of these disadvantaged groups is crucial in the striving for sustainable agriculture.

Conclusion

The agricultural sector has multiple roles in developing countries: to help ensure food security, to anchor rural development, and provide resources for the livelihood and adequate incomes of the majority of people, all without destroying the environment. There are thus two inextricably linked components, the social and environmental, to agricultural sustainability.

The erosion of the spirit and practice of international cooperation, especially on a North-South basis, is having serious repercussions on agriculture and rural development in developing

countries. This erosion of international cooperation is most noticeable in the decline in aid; but the globalisation process, facilitated by structural adjustment, the Uruguay Round, and the WTO, has even more serious implications (see Chapter 4). It is imperative that a change of mindset takes place, to review the present damaging framework and build a new paradigm of policies that can promote sustainable agriculture. Whether such a paradigm shift takes place is the acid test of the success or failure of sustainable development in the years ahead.

The rich countries have been notorious for their high protection and subsidy for their own farm sector. The AoA has allowed them to continue high protection through tariffs (some at 100 to 300 percent) as well as export and domestic subsidy. The OECD countries' total domestic farm subsidies rose from US\$275 billion (annual average for 1986-88) to US\$326 billion as an increase in 'non trade distorting subsidy', which more than offset the 'trade distorting subsidy'



Landless peasants demonstrating against globalisation at World Social Forum, Brazil, 2001

- 4 -

Agriculture without Farmers

EU, US and WTO agricultural policies are sweeping farmers off the land, creating poverty and threatening world food security

Farming has evolved over thousands of years with the farm as the basic unit of local community and culture. Its practice was shaped everywhere by geography and the creative skills of the farmer. Since the arrival of the tractor and the industrial Green Revolution in the 1940s, small family farms have lost out to big industrial farms, and much of the local knowledge has disappeared

Trade policies benefit agribusiness and displace small farmers

In industrialized countries like the UK where the population is largely urban, 200 000 farms have disappeared between 1966 and 1995 [1]. The annual UK Common Agricultural Policy budget of £3 bn gives 20 percent of farmers (large agribusinesses) 80 percent of subsidies. Government figures show that 17 000 farmers and farm-workers left the land in the year 2003 [2].

While only five percent of the population in the European Union (EU) are still farming [3], at least half a million farm-workers were still leaving the land annually before the EU was enlarged by 15 new members in May 2004. It is likely that Poland alone will lose up to two million agricultural livelihoods as a result of joining the EU [1]. EU figures suggest that half of north European agriculture will disappear within a generation [4] as it continues to be squeezed out by the institutions that claim to give it support.

'Free trade' policies made by and for the rich countries of the North not only destroy the livelihood of small-farmers at home, they also encourage the dumping of subsidized goods (selling at less than the cost of production) from the North onto the markets of the poor South, distorting local markets, and leaving farmers in developing countries unable to compete

In the US, between 1950 and 1999, the number of farms decreased by 64 percent to less than two million, and farm population has declined to less than 2 percent. Ninety percent of agricultural output is produced by only 522 000 farms [5]. Canadian statistics similarly reveal that farm numbers have decreased by 10 percent between the 1996 census and 2001; there were less than 247 000 farms in the country in 2001 [6].

This relentless process of consolidation drives the heart out of the countryside, causing social

and economic decay, and replaces it with an intensive industry that cares nothing about plant or animal diversity, quality or compassion in farming, but is solely interested in bringing down prices and maximising corporate profit [1, 7].

'Free trade' policies made by and for the rich countries of the North not only destroy the livelihood of small-farmers at home, they also encourage the dumping of subsidized goods (selling at less than the cost of production) from the North onto the poor South (see Chapter 3), distorting local markets, and leaving farmers in developing countries also unable to compete [1, 7, 8].

This has become a global scandal, as 75 percent of the population in China, 77 percent in Kenya, 67 percent in India, and 82 percent in Senegal still depend on farming for their living [3]. These numbers are plummeting, however, as families dispossessed of their land are driven to the cities, where they may find themselves unable to afford to pay for the food they used to grow. An epidemic of suicide has taken its toll of India farmers as problems of low commodity prices are compounded by massive failures of the GM crops planted (see Chapter 23).

Agribusiness degrades the environment while governments do nothing

'Free trade' policies of World Trade Organization (WTO) promote overproduction of agricultural commodities causing damage to wildlife, depleting soil, water, and fossil fuels; at the same time compromising food quality and impacting on public health [1, 7]. Free trade policies also exacerbate global warming in many ways, not least the millions of unnecessary food-miles added to agricultural commodities (see Chapter 8).

Jules Pretty of Essex University estimated that the total external costs for conventional agriculture in the UK, paid for by the taxpayer, added up to £2.34 bn for the year 1996 [9].

The UK government remains a chief obstacle in the fight against poverty and environmental degradation despite its seemingly green credentials on climate change and high media profile in tackling poverty in Africa. That is because it continues to espouse an economic model that promotes privatisation and trade liberalisation as the key to reducing poverty and protecting the



environment, a model that has proved to have just the opposite effects (see Chapter 2). The UK has been at the forefront of EU efforts to push through an aggressive 'free trade' agenda at the WTO [10].

Our governments have stood by while a few transnational corporations developed a stranglehold over global food security through consolidating ownership of seed, chemicals and other inputs, as well as virtual monopoly of food processing and retail outlets [2, 7, 11].

The Agreement on Agriculture of the WTO and the Common Agricultural Policy of the European Union are largely responsible for this global disaster in our food system (see Chapter 3).

The Common Agricultural Policy of the European Union

When the EU introduced the Common Agricultural Policy (CAP) in the early 1960s, it struck a deal with the US under the framework of the General Agreement on Trade and Tariffs (GATT). The US accepted the new border protection mechanisms put in place by the EU for food in return for a commitment by the EU to allow unlimited import of feedstuffs from the US at zero tariff. The EU agreed because it was still a net importer of food and feedstuffs. But only 15 years later, the EU itself was producing more, and ended up with

large surpluses of grain and animal products as a direct result of this deal [12].

The zero tariff for feedstuffs enabled Europe's huge surpluses of the 1970s to be dumped on developing countries..

The CAP, which aimed to "ensure a fair standard of living for the agricultural community" [2], has for many years provided direct aid to farmers based on area, production, and number of livestock units (animals) [13]. It gave large monocultural farms enormous subsidies, causing excessive overproduction that lowered prices, driving out small farmers, and consolidated the power of agribusiness. Farmers buy seeds, pesticide, machinery etc at great expense from the same transnational corporations that purchase their produce at below costs and selling it on to consumers at enormous profit [7, 14].

The CAP reform of 2003 introduced a new system of single farm payments that decouples the link between support and production. It came into force in 2005-6 except for new member states, and its stated aim was to ensure greater income stability for farmers, leaving them free to decide what they want to produce in response to demand, without losing their entitlement [13]. However, this is not the effect it will have.

Farm business consultants Andersons and the National Farm Research Unit predicted a further

30 percent decrease in British cereal growers and another 35 percent decrease in dairy farmers when the new single farm payments kicked in. These payments will be lower than the previous payments made to smaller farms [14].

'Free trade' policies of World Trade Organization promote overproduction of agricultural commodities causing damage to wildlife, depleting soil, water, and fossil fuels; at the same time compromising food quality and impacting on public health

A survey of English farmers showed that 87 percent did not want subsidies, only a fair return on their costs of food production. Figures from the Department of the Environment, Food and Rural Affairs (Defra) showed average farm income in 2002 at £10 000 (which was below the income for the lowest 10 percent [15]), with farm-gate prices having risen just 2 percent in the past seven years. Meanwhile, supermarket prices have risen by 21 percent, and in 2002-3, Tesco's profits were 60 percent of total UK farming income [2].

CAP reform was also greeted with dismay abroad. NGOs such as the Catholic aid agency CAFOD and Oxfam said it would be "dumping as usual" for developing countries [16].

CAP has positively encouraged the most senseless and environmentally destructive "food swaps". Britain imported 61 400 tonnes of poultry meat from the Netherlands in the same year that it exported 33 100 tonnes of poultry meat to the Netherlands. Britain imported 240 000 tonnes of pork and 125 000 tonnes of lamb, while it exported 195 000 tonnes of pork and 102 000 tonnes of lamb [17]. In 1997, 126 million litres of liquid milk were imported into the UK and at the same time 270 million litres of milk were exported out of the UK. Twenty three thousand tonnes of milk powder were imported into the UK and 153 000 tonnes exported out [18]. In 1996 the UK imported 434 000 tonnes of apples, nearly half of which came from outside the EU. Yet over 60 percent of the UK's own apple orchards have been grubbed up since 1970, largely as a result of EU subsidies [19].

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US agricultural policy

US agricultural policy has traditionally promoted cumulative growth [20] and privatisation of seed at taxpayer's expense [21]. That has wrung all the profit out of farming and into trading, processing, and retailing, controlled by a few transnational corporations [11, 20, 22]. The share of the US agricultural economy going to farmers declined from 41 percent in 1910 to 9 percent in 1990, while farm input and marketing industries' shares increased by the corresponding amount [22].

As small farmers are pushed out, others enlarge their operation, for example, in the US pig industry a quarter of all producers went out of work between 1998 and 2000, leaving just 50 businesses controlling 50 percent of all US production. Yet, independent pig farmers produce more jobs, more local retail spending, and more local per capita income than larger corporate operations; and profits generated by small producers (of any commodity) are more likely to remain in the community and benefit the local economy.

As in Europe, these policies have drastically eroded plant and animal genetic diversity. They have resulted in low farm prices, many small farms failing, and environmental degradation. And because the policies are geared towards maximising export, similar effects are spreading all over the world. Seventy percent of the world's poorest people, who directly depend on the land, are forced to compete with the rich nations [11].

The Agreement on Agriculture of the WTO

The 1996 Freedom to Farm Bill followed by the 2002 US Farm Bill produced a vast structural oversupply of major agricultural commodities in an attempt to comply with WTO rules [19, 23]. The Agreement on Agriculture (AoA) came out of the Uruguay Round of the General Agreement on Tariffs and Trade (GATT) negotiations between the US and the EU (1986-94) that led to the founding of the WTO [12]. It provides the rules governing international agricultural trade and, by extension, agricultural production [8].

The AoA is based on the firm ideological belief that trade liberalization brings net benefits to all participants. By removing barriers to trade, regional specialization will increase and regions will specialize in whatever their agriculture can produce more cheaply than others. It dictates that when products are exchanged, everybody gains because the combined cost of production is less than if each region had produced its own. In practical terms, this means promoting exports and limiting the right of countries to follow a policy of food self-sufficiency [12].

The aim of the AoA is to reduce the use of methods that favour domestic production: border protection against imported products (the cheapest and most widespread method used); internal support measures for domestic producers (mainly used by developed countries with taxpayers money); and export subsidies (used exclusively by developed countries).

But the US claims the right to spend tens of billions of dollars to compensate farmers for market failures rather than addressing those failures directly [8, 19]. In 2003, over half of the compensation went to less than 2 percent of farmers, again benefiting only very large businesses [24]. Furthermore, developed countries maintain the right to continue with several forms of support that are now illegal for any other country [12] (see Chapter 3).

The US, with its chronic overproduction in major commodities, always needs new export markets. For example, rice, the staple of most of

the poor nations, is grown on around 8 000 farms in the US; half in Arkansas where the biggest 332 rice farms, each over 400 hectares in size, produce more rice than all the farmers of Ghana, Guinea, Guinea-Bissau, Niger, and Senegal combined [25].

In 2003, the US's crop of 9 m tonnes of rough rice cost farmers \$1.8 bn to produce. Farmers received only \$1.5 bn from rice millers, but were sustained by government subsidies, which totalled \$1.3 bn. Between 2000 and 2003 it cost on average \$415 to grow and mill one tonne of white rice in the US, but that rice was exported around the world for just \$274 per tonne and dumped on developing country markets at a price 34 percent below its true cost [26].

Surpluses may also be designated 'food aid' and monetized, i.e., sold on the recipient country's market to generate cash. Most US programme food aid is sold to recipient countries through concessional financing or export credit guarantees. The US is nearly the only country that sells 'food aid' to recipient countries; other donors give it in grant [26], but both strategies reduce prices for developing country exporters and for small-holders in importing countries, and deepen and prolong the depression in world market prices [25].

Current agriculture policies undermine human rights

The WTO's stated aims are to raise living standards, ensure full employment, and raise incomes; and the AoA is specifically meant to further the WTO's aims by "establishing a fair and market oriented agricultural trade system". But a report by the Institute for Agriculture and Trade Policy released in March 2005 accused WTO agriculture policies of undermining human rights.

The WTO agricultural policies adhere to a trade liberalisation agenda that overrides efforts to improve livelihoods [27] by promoting the 'right to export' over human rights; failing to tackle corporate control; allowing export dumping at artificially low prices to continue; and locking developing countries into an uneven playing field.

Data from the US Department of Agriculture and the Organization for Economic Cooperation and Development (2003) showed how exports from US-based global food companies were dumped onto world markets [23]. Wheat was exported on average 28 percent below cost; soybeans and corn, 10 percent; rice, 26 percent; and cotton, a whopping 47 percent below cost.

This dumping has greatly increased since the inception of the AoA [23], and prices have dropped to new lows [12]; but as all WTO members have ratified at least one of the international human rights treaties, these instruments could be used when designing trade policies [27].

The policies of international agribusiness

The laws that bind international trade derive from the ideology of international agribusiness whose common interest lies in opening up developing country markets. Close links with governments and academia are exploited to persuade policy-

makers and the public that trade liberalization is clearly in the best interest of developing countries [25].

Agribusiness is at the heart of US trade policy, thanks to the Agricultural Technical Advisory Committees for Trade. Members appointed in 2003 were selected, according to former US Trade Representative Robert Zoellick [25], to "coincide with the continuation of the Bush Administration's aggressive push to open foreign markets to US agricultural products.... Coordinating with our agricultural community will continue to be important as the tempo of negotiations for global, regional, and bilateral trade agreements intensifies."

The WTO agricultural policies promote the 'right to export' over human rights, failing to tackle corporate control, allowing export dumping at artificially low prices, and locking developing countries into an uneven playingfield

In the US, as in many other countries, there is a fast-revolving door between top posts in agro-industry and government; and agribusiness sits in the top ten of industry donors to candidates and political parties in US elections, contributing over \$340 m to campaign funds since 1990.

Their policies have reinforced industrial agriculture at the expense of sustainable agriculture. During this multinational bonanza, industrial agriculture and its policies are placing enormous stress on the world's small farmers and the renewable resource base, especially water and soil. Moreover, the local knowledge and plant genetic diversity most needed to truly sustain the world are being lost. Recent research has demonstrated the resilience and productivity of many traditional agricultural practices that have withstood the test of time [7, 22, 28, 29] (see many chapters in this volume).

Studies have documented the damage done when small, diverse organic farms - that have only one third of the hidden costs of non-organic agriculture - are pushed off the land by distorted markets [30] and replaced with large monocultures oriented towards export [8]. But government policies tend to emphasize a handful of major crops that require large fertilizer and pesticide inputs, and ignore resource conserving crop rotations for which farmers receive no government incentives, or sustainable practices such as growing clover or alfalfa to enhance soil fertility. Governments also perpetuate chemical-intensive agriculture by funding research on chemical fixes for agricultural problems, to the exclusion of research on more sustainable options [21].

Sustainable systems are especially able to compare favourably with conventional systems when full account is taken of the environmental and public health damages/benefits; but these costs associated with conventional systems are usually externalized, or paid by society rather than the polluter [21].

There needs to be dedicated support for sustainable food production by small farmers who have served us well for thousands of years; and a curbing of the power of multinationals who serve only themselves.

Changes to agricultural trade policies needed

The International Commission on the Future of Food and Agriculture suggests the following changes to agricultural trade policy that would help make the world a much fairer and healthier place [7]:

Permit tariffs and import quotas that favour subsidiarity

That means whenever production can be achieved by local farmers using local resources for local consumption, all rules and benefits should favour that option; thus shortening the distance between production and consumption. Trade should be confined to whatever commodities cannot be supplied at the local level, rather than export trade being the primary driver of production and distribution.

Reverse the present rules on intellectual property and patenting

The current regime of intellectual property rights and patenting strongly favour the rights of global corporations on patent claims to medicinal plants, agricultural seeds, and other aspects of biodiversity, even when the biological material has been under cultivation and development by indigenous people or community farmers for millennia. This must be reversed.

Localize food regulations and standards

Rules that benefit global food giants, such as irradiation, pasteurization, and shrink-wrapping also negatively affect taste and quality; and industrial processing has led to an increased incidence of food poisoning and diseases in farm animals. Each nation should be allowed to set its own high standards for food.

Allow farmer marketing/supply management boards

These let farmers negotiate collective prices with domestic and foreign buyers to help ensure that they receive a fair price for their commodities. The North American Free Trade Area dismantled government price regulation agencies, and two years after it went into effect, Mexican domestic corn prices fell by 48 percent as a flood of cheap US corn exports entered the country. Thousands of farmers have been forced to sell their lands.

Eliminate direct export subsidies and payments for corporations

Although the WTO has eliminated direct payment programmes for most small farmers, they continue to allow export subsidies to agribusinesses. For example, the US Overseas Private Investment Corporation funded by US taxpayers provides vital insurance to US companies investing overseas. Even loans from the IMF to Third World countries have been channelled into export subsidies for US agribusiness.

Recognize and eliminate the adverse effects of WTO market access rules

Countries need new international trade rules that allow them to re-introduce constraints and controls on their imports and exports. These would prevent heavily subsidised Northern exports from destroying rural communities and self-sufficient

livelihoods throughout the South. For example, many people now working for poverty wages at Nike and other global corporate subcontractors are refugees from previously self-sufficient farming regions.

Promote redistributive land reform

The redistribution of land to landless and land-poor rural families is a priority. This has promoted rural welfare at different times in Japan, South Korea, Taiwan, China and Cuba (see Chapter 12). Research shows that small farmers are more productive and more efficient, and contribute more to broad-based regional development than do the larger corporate farmers (see Chapter 22).



- 5 -

Biofuels = Biodevastation, Hunger & False Carbon Credits

A mandatory certification scheme for biofuels is needed to protect the earth's most sensitive forest ecosystems, to stabilise climate and to safeguard our food security

Biofuels not necessarily carbon neutral nor sustainable

Biofuels are fuels derived from crop plants, and include biomass directly burnt, and especially biodiesel from plant seed-oil, and bioethanol from fermenting grain, sap, grass, straw or wood [1].

Biofuels have been promoted and mistakenly perceived to be 'carbon neutral', that they do not add any greenhouse gas to the atmosphere; burning them simply returns to the atmosphere the carbon dioxide that the plants take out when they were growing in the field. This ignores the costs in carbon emissions and energy of the fertiliser and pesticides used for growing the crops, of farming implements, processing and refining, refinery plants, transport, and infrastructure for transport and distribution. The extra costs in energy and carbon emissions can be quite substantial particularly if the biofuels are made in one country and exported to another, or worse, if the raw materials, such as seed oils, are produced in one country to be refined for use in another. Both are likely if current trends continue. And above all, biofuels that involve cutting down forests to plant bioenergy crops are the quickest ways of creating huge carbon emissions.

Growing demand for biofuels in US and EU

Demand for biofuels has been growing as the world is running short of fossil fuels. Oil and gas prices have shot up within the past several years, while the pressure to reduce carbon emissions to mitigate global warming has pointed towards biofuels as one of the main solutions. George W. Bush offered biofuels to cure his country's addiction to oil [1]. A "billion ton vision" was unveiled [2] to make available 1.3 billion tons of dry biomass for the biofuels industry by the middle of this century, to provide 30 percent of US' fuel use, if all things work out as projected, such as a fifty percent increase in crop yield. Biofuels Corporation plc, the first 250 000 Mt biodiesel processing plant in the UK was opened by Tony Blair at the end of June 2006 [3]; it would be using imported castor oil and palm oil as well as home grown rapeseed oil to make biodiesel. However, the company stopped trading in August 2007 [4].

The European Union adopted a Biofuels Directive in May 2003 to promote the use of biofuels in transport at 5.75 percent of market share by 2010, increasing to 8 percent by 2015 [5]. These targets are not likely to be met on current projections. The market share for EU25 was 1.4 percent in 2006; Austria led at 2.5 percent, while UK's share was a mere 0.2 percent. But the Biofuels Directive has produced a biofuel buzz if not boom in Europe [6].

The European Commission (EC) made a progress report for public consultation, which ended in July 2006. Among the issues considered was the need for a biofuels certification scheme based on standards of sustainability. The European Parliament passed a resolution 25 September 2007 supporting the EC plan of a mandatory 10 percent blend of biofuels by 2020, but sustainable methods must be used and the resolution includes a proposal for a compulsory certification system [7].

There is no spare land for energy crops

The International Energy Authority 2004 report on biofuels [8] estimated that a 10 percent



Oilpalm plantations in Malaysia

substitution of fossil fuels would require 43 percent and 38 percent of current cropland area in the United States and Europe respectively. That means forests and grasslands would need to be cleared even at this low level of substitution, and this is indeed the case.

EU countries are already growing bioenergy crops, mainly oil seed rape; and tax relief and incentives are granted in ten or more countries [9]. Europe's 'set-aside' agricultural land, meant for protecting and conserving biodiversity, has been suspended for 2008, and is likely to be brought back permanently into agriculture, to meet the demand for bioenergy crops and the shortfall in grain yields from recent droughts and floods [10].

A report published in 2002 by the CONCAWE group - the oil companies' European association for environment, health and safety in refining and distribution - estimated that if all 5.6 million hectares of set-asides in the EU15 nations were intensively farmed for bioenergy crops, we could save merely 1.3-1.5 percent of road transport emissions, or around 0.3 percent of total emissions from those 15 countries [11]. The EU's own technical report published in 2004 shows that the target of 5.75 percent for fossil fuels will require at least 14 to 19 percent of farmland to grow bioenergy crops [12]. Calculations based on the best-case scenario of unrealistically high crop yields and high recovery of biofuels from processing still end up requiring 121 percent of all the farmland in the United States to grow enough biomass to substitute for the fossil fuels consumed each year [1]. These pessimistic estimates are fuelling the growth in biofuels industries in Third World countries, where, we are now told, there is plenty of "spare" land for growing bioenergy crops. The sun shines brighter all year round, so crops grow faster, yield more and labour is cheap.

Biofuels generally give small to negative energy balance on a life-cycle analysis. It is likely that carbon savings will be equally unfavourable when all the costs are included

In the case of GM crops, we're told there isn't enough land, and we need GM crops to boost yields to feed the world. GM crops have failed to boost yields so far, and are overwhelmingly rejected worldwide, especially in African countries where GM food and feed are being dumped as 'food aid' [13]. Biotech companies are already promoting GM bioenergy crops and hoping for less regulation and more public acceptance, as they won't be used as food or feed. But that will leave our ecosystem and food crops wide open to contamination by GM crops that are far from safe [14]. The United Kingdom Energy Research Centre, which consists of members from all the government research councils, has already included "public perception and use of GM technologies for bioenergy" in its "Short term Research Challenge" [15].

Satellite data reveal that 40 percent of the earth's land is used for agriculture [16], either growing crops or for pasture. There is no spare land for growing food, let alone bioenergy crops that have the same requirements for arable land.

Biofuels are bad news, especially for poor Third World countries. Bioenergy crops do take up valuable land that could be used for growing food, and food security is becoming a burning issue. World grain yield has fallen for six of the past seven years, bringing reserves to the lowest since the 1980s (see Chapter 1). The pressure on land from food and bioenergy crops will certainly speed up deforestation and species extinction, and at the same time increase food prices worldwide, hitting the poorest, hungriest countries the hardest.

Deforestation and species extinction

Tropical forests are the richest carbon stocks and the most effective carbon sinks in the world. Estimates run as high as 418 t C/ha in carbon stock, and 5 to 10 t C/ha a year sequestered, forty percent of which is in soil organic carbon [17]. The carbon stock in old growth forests would be even greater, and according to a recent study in Southeast China, soil organic carbon just in the top 20 centimetres of such old growth forests increased on average at a rate of 0.62 t C/ha each year between 1979 and 2003 [18]. When tropical forests are cut down at the rate of more than 14 m ha a year, some 5.8 Gt C of carbon stock is made available for release to the atmosphere over a period of time, only a fraction of which would be sequestered back in plantations.

The additional pressure on land from bioenergy crops will mean yet more deforestation and a greater acceleration of global warming and species extinction.

Vast swathes of the Amazon forest in Brazil have already been cleared for soybean cultivation to feed the meat industry so far. Adding soybean biodiesel to the requirement may cause the entire forest to die back. At the same time, sugarcane plantations that feed the country's mammoth bioethanol industry also encroaches on the Amazon, but far more so on the Atlantic forest and the Cerrado, a very bio-diverse grassland ecosystem, two-thirds of which are already destroyed or degraded [19].

The pressure on the forests in Malaysia and Indonesian is even more devastating. A Friends of the Earth Report, *The Oil for Ape Scandal* [20] reveals that between 1985 and 2000 the development of oilpalm plantations was responsible for an estimated 87 percent of deforestation in Malaysia. In Sumatra and Borneo, 4 million hectares of forests were lost to palm farms; and a further 6 m ha are scheduled for clearance in Malaysia and 16.5 m ha in Indonesia.

Palm oil is rightly referred to as "deforestation diesel" [21], as palm oil production in Indonesia and Malaysia is projected to rise dramatically in the biofuels fever. Palm oil has been widely used in the food and cosmetic industry, having replaced soy as the world's leading edible oil. And as petrol and gas prices have gone through the roof, oil palm is finding its place as the major bioenergy crop. With yields of 5 tonnes (or 6 000 litres) of crude oil per ha a year, oilpalm produces more by a long shot than any other oil crop [22]; for example, soybeans and corn generate only 446 and 172 litres per ha a year.

Current global palm oil production of more than 28 million tonnes per year is set to double by 2020 [21]. Malaysia, the world's leading producer and exporter of palm oil, is making it mandatory for diesel to contain five percent palm oil by 2008, while Indonesia plans to halve its national consumption of petroleum by 2025 through substitution with biofuels. Malaysia and Indonesia have announced a joint commitment to each produce 6 million tonnes of crude palm oil per year to feed the production of biofuels.

Food price hikes as more diverted into biofuels

As demand for biofuels has turned traditional food crops into bioenergy crops, food and energy compete for the same 'feedstock', with the result that food prices have gone up substantially, over and above the price of petroleum and natural gas that normally goes into producing food. By 2006, around 60 percent of the total rapeseed oil produced in the EU went into making biodiesel [23]. The price of rapeseed oil increased by 45 percent in 2005, and then an additional 30 percent to about US\$800 per tonne. Food giant Unilever estimated further price increases of some 200 euros per tonne for the next year due to additional biodiesel demand, which would translate to an additional cost to food manufacturers of close to one thousand euros by 2007.

US corn prices have increased by more than 50 percent since September 2006, hitting a 10-year high at US\$3.77 a bushel in 2007. US demand for bioethanol has diverted corn from exports, leaving Asia corn buyers desperate [24]. World wheat prices reached an all-time high of \$7.54 a bushel by August 2007, having risen threefold since 2000 [25].

Soaring food prices worldwide are threatening political stability. Food riots or near food-riots have been reported in India, Yemen, Mexico, Burkina Faso, West Bengal and several other countries over the past year [26], and governments have been forced to artificially control the price of bread, maize, rice and dairy products.

Other environmental concerns

Bioenergy crops deplete soil minerals and reduce soil fertility especially in the long term, making the soil unsuitable for growing food. The processing wastes from all biofuels have substantial negative impacts on the environment, which have yet to be properly assessed and taken into account. Although some biodiesel may be cleaner than diesel, others are not (see below). Burning bioethanol generates mutagens and carcinogens and increases ozone in the atmosphere [27].

Research conducted at the Flemish Institute for Technological Research, sponsored by the Belgian Office for Scientific, Technical, and Cultural Affairs and the European Commission stated that [28]: "...biodiesel fuel causes more health and problems because it created more particulate pollution, released more pollutants that promote ozone formation, generated more waste and caused more eutrophication." Hence, "The benefits biodiesel fuel offers in terms of reducing

greenhouse gas emissions do not justify its use in light of the other environmental damage it causes..."

Energy balance and carbon savings unfavourable on the whole

Biofuels are rated on energy and carbon in many ways. The ones used here are energy balance, the units of biofuel energy produced per unit of input energy; and carbon saving, the percentage of greenhouse gas emissions prevented by producing and using the biofuel instead of producing and using the same amount of fossil energy.

Biofuels generally give small to negative energy balance on a life-cycle analysis, in fact, mostly negative energy balance when proper accounting is done [1], which means that the energy in the biofuel is less than the sum of the energy spent in making it. It is likely that carbon savings will be equally unfavourable when all the costs are included.

Currently, most energy audits that give positive energy balance include energy content of by-products, such as the seedcake residue left over when oil has been extracted, that can be used as animal feed (though it is by no means so used as a rule) [11], and fail to include infrastructure investments, such as the energy and carbon costs of building refinery plants, and roads and depots needed for transport and distribution; and certainly not the costs of exporting to another country. None of the audits includes environmental impacts [6] (see above).

A compilation of energy balance and carbon saving estimates is given in Box 5.1.

Sugarcane ethanol in Brazil is estimated to have an energy balance of a staggering 8.3 on

Box 5.1

Biofuels Energy Balance and Carbon Saving

	Energy Balance	C Saving
Biodiesel		
OSR (EU) ¹⁰	1.59	52%
OSR (UK) [28]	1.78	
OSR (EU) [8]	1.90	
OSR (Australia) [29]		50%
Soya (USDoe) [30]	2.22	40%
Soya (US) [31]	0.53*	
Ethanol		
Wheat & sugarbeet (EU) [10]	1.08	27%
Corn (US) [10]	1.113-1.34	13%
Corn (US) [31]	0.78*	
Corn (US) [32]	1.14	11%
Corn (US) [10]	0.61	-30%
Corn (US) [10]	1.65	
Maize (N France) [10]	1.03	24%
Maize (N. France) [10]	0.94	17%
Sugarbeet (EU) [8]	1.18	
Wood (US) [10]	0.64	
Wood (Scand) [10]	0.80	
Sugarcane (Brazil) [33]	8.30-10.20	85 - 90%

*Includes infrastructure costs and excludes by-products

average, and up to 10.2 in the best case; far ahead of any other biofuel, especially those produced in temperate regions, estimates for which range from a high of 2.2 to well below 1, a negative energy balance. The carbon saving of Brazilian sugarcane ethanol at between 85 and 90 percent, is also bigger by far than any other biofuel, which ranges from just over 50 percent to -30 percent, i.e., the biofuel incurs 30 percent more greenhouse gas emissions to produce and use than the energy equivalent in fossil fuel.

With two exceptions, all estimates include energy in byproducts and exclude infrastructure costs. None include environmental damages or depletion of soil, or costs of export to another country. As can be seen, with the possible exception of Brazilian sugarcane ethanol, none of the bioenergy sources gives good enough returns on investments in energy and carbon emissions, even with the best gloss put on. When realistic accounting is done, they could all result in negative energy balance and carbon saving.

There are features that account for the favourable energy and carbon emissions balance of sugarcane ethanol. Apart from the prolific growth rate of the crop in tropical Brazil, the production involves a closed cycle, where the energy for the refinery and distillery process comes from burning sugarcane residue; hence no fossil fuels are needed. Refining and distillation are very energy intensive especially for ethanol. The large energy balance will be reduced substantially when infrastructure and export costs are included, though it could still be positive.

But even with the positive energy and carbon accounting, there are serious doubts that sugarcane ethanol is sustainable [19]. Among the main concerns are ecological and social impacts, including food security. These are especially important in a country where human rights and land rights are very problematic. In October 2007, two men were killed and five wounded when guards working for the Swiss biotech company Syngenta clashed with Brazilians invading a GM seed farm in Parana state. The group Via Campesina had organised the action in protest at what they called the illegal growing of the seeds [35]. Such clashes between landless peasants reclaiming land for growing food and guards hired by companies are frequent occurrences, with the government failing to protect the people involved.

Planting a forest in the same area of land would sequester two to nine times more carbon over a 30-year period than the emissions avoided by using biofuels. The most disastrous option is to convert tropical forest into cropland, which leads to a net loss (emission) of 200 t C/ha

There is a lot of false accounting that inflates carbon savings. For example, the huge loss of soil organic carbon due to intensive sugarcane cultivation replacing forests and pastureland has not been taken in account [36], nor the fact that natural forests allowed to regenerate would save seven more tons of carbon dioxide emission per ha each year than that the bioethanol from a ha of sugarcane [37]. And these are not the only forms

of false accounting.

False carbon credits in southern Africa's jatropha biodiesel

Under international rules, none of the greenhouse gas linked to the production of biofuels will be attributed to the transport sector. They will be counted towards agricultural and industry and or energy sector emissions. Also, all the emissions that come from growing and refining in Third World countries will count towards those countries' emissions, so a country importing the biofuel such as the UK can use them to improve its greenhouse gas inventory. This allows rich importing nations to out-source some of their emissions and claim credit for doing so under the Kyoto Agreement [37]. This is how plantations of jatropha trees have become established in Malawi and Zambia,

We are told that jatropha is a drought resistant plant that requires little or no input of pesticides or fertilisers. Jatropha beans can be harvested three times a year, and the by-products can be used to make soap and even medicine. Refining is done in South Africa. Many farmers switched from tobacco to jatropha, considered a good thing as tobacco is a very environmentally unfriendly plant to grow. So far there are 200 000 ha of jatropha in Malawi and 15 000 ha in Zambia, almost all under agreements with the UK-based company D1 Oils.

However, biodiesel entrepreneur Louis Strydom, in trying to establish a biodiesel plantation and refinery on a massive scale in Kenya, found that while subsistence biofuel production and refining as a supplemental crop by small farmers around the world is a viable economic model, large commercial scale production is quite a different matter. For one thing, the yields and multiple harvests of jatropha have been grossly exaggerated, and in any case, can only be achieved under optimum conditions of rainfall, soil quality, and applications of insecticide and fertilizer [38]. Southern Africa is one of the most vulnerable regions in the world to climate change. All climate models predict that the region (not including most of South Africa, Lesotho and Swaziland) will become a lot warmer and drier, with more frequent and severe droughts, interspersed by more severe flooding [37]. This could cause massive crop failures and a collapse of food production.

About 80 percent of Zambia's population rely on biomass for all or most of their energy needs, with only 12 percent having access to electricity. In Malawi, 90 percent of primary energy production comes from biomass, i.e., firewood and charcoal. Most rural people rely on burning firewood, often on inefficient cooking stoves, which causes serious pollution and are a major cause of ill health and death. Women and girls are particularly affected. Large-scale jatropha plantations may have serious impacts on the food and energy security of the region, especially if they expand.

The jatropha bubble has also hit India [39] while its socio-economic and environmental impacts are being ignored.

Saving and restoring forests saves far more carbon emissions than biofuels

Perhaps the most powerful argument against biofuels is the demonstration that saving and restoring forests saves far more carbon emissions.

Rento Righelato from the World Land Trust, Suffolk, and Dominick V Spracklen at the University of Leeds in the UK have compared the carbon mitigation potentials of various biofuels with other uses of the land required for growing the bioenergy crop [40]. As land is the limiting resource, they argue, the appropriate basis for comparison is the amount of C saved per hectare for a number of years and they assume a reasonable period is 30 years. Their results are summarised in Figure 5.1.

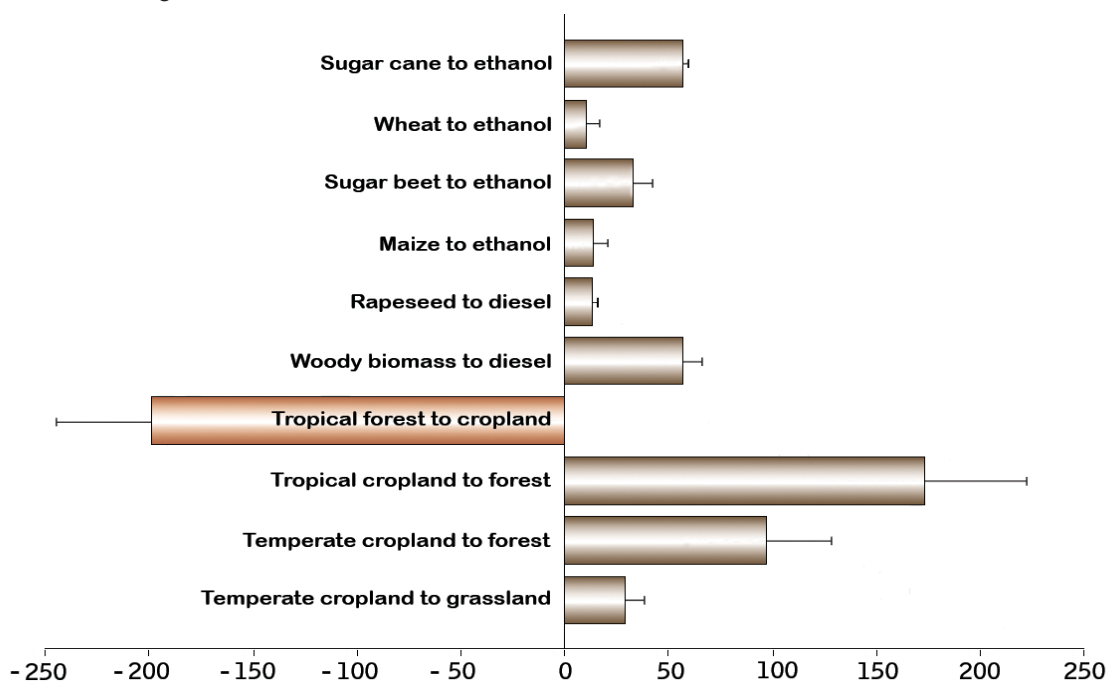


Figure 5.1. Carbon saved (t/hectare)

They have made no allowance for emissions arising from change in land use to produce the bioenergy crop. As can be seen, planting a forest in the same area of land would sequester two to nine times more carbon over a 30-year period than the emissions avoided by using biofuels.

The most disastrous option is to convert tropical forest into cropland, which leads to a net loss (emission) of 200 t C/ha. The Stern Report [41] on the economics of climate change commissioned by the UK Treasury noted that putting a stop to deforestation is by far the most cost-effective way to mitigate climate change, for as little as \$1/t CO₂ [42].

Righelato and Spracklen point out that of the options for biofuels, only conversion of woody biomass may be compatible with retention of forest carbon stocks, especially if it means making use of wood wastes and harvesting appropriately from standing forests. This would mean selective felling of the biggest tree, which has been shown to encourage the most carbon assimilation in new growth and result in the most benefit for biodiversity (see Chapter 30).

If the prime object of policies on biofuels is

mitigating carbon emissions, Righelato and Spracklen note: "policy-makers may be better advised in the short term (30 years or so) to focus on increasing the efficiency of fossil fuel use, to conserve the existing forests and savannahs, and to restore natural forest and grassland habitats on cropland that is not needed for food."

Apart from reducing net CO₂ emissions, conversion of large areas of land back to secondary forest provides other environmental services, such as prevention of desertification and maintenance of regional climate regulation (see Chapter 25), providing forest products, maintenance of biodiversity.

Moratorium on biofuels

The UN 'Right to food' rapporteur Jean Ziegler urges a 5-year moratorium on biofuels [46]. Among the potential impacts identified are increasing food prices, increasing competition over land and forests, forced evictions, impacts on employment and conditions of work, and increasing prices and scarcity of water.

Ziegler's proposal for moratorium aims to ban the conversion of land for the production of biofuels, and is not aimed at small-scale sustainable production of biofuels by subsistence farmers [39]. He hopes that by the time the moratorium is lifted science would have made sufficient progress to be able to create "second generation" biofuels, made from agricultural waste or from non-agricultural plants such as jatropha, which grows naturally on arid ground.

The only 'biofuel' that is truly sustainable is methane from anaerobic digestion of biological and livestock wastes [43, 44]. Other renewable and sustainable energy options are described in our 2006 Energy Report [45]. These options can be assembled in a zero-emission, zero-waste food and energy 'Dream Farm 2' (see Chapter 34).

- 6 -

Save Our Seeds

New threats from genetic engineering to the world's gene banks highlights the importance of *in situ* conservation and seed saving in local communities for sustainable food systems and food security

World gene banks and food security in jeopardy

Deteriorating conditions in the world's crop gene banks pose "a major threat to US agriculture," says a study published by the University of California Genetic Resources Conservation Program [1]. The report notes that nearly every major crop in the United States - including soybeans, corn, wheat, rice, potatoes, oranges and apples - is battling a plethora of new or re-emerging pests to which there is little or no resistance. Failure to adequately maintain crop gene bank collections "could constrain agriculture's ability to avert billions of dollars in crop damage."

75 percent of the genetic diversity of agricultural crops had been lost during the last century of industrial monoculture

These gene banks provide the diversity needed to enable the crops "to stay one step ahead of pests", and also to improve quality, nutritional value, and yield. But lack of funding has left many of the collections in a state of decay.

Just prior to the publication of the report, Nobel Peace Prize laureate Norman Borlaug was warning the world of a new rust epidemic from East Africa, that, if it gets loose in Asia, North America, South America and Australia, would infect half of all our grain varieties, and the stage would be set for a major disaster. This calls for ongoing research. Borlaug could have admitted that these disease pandemics are a direct result of the Green Revolution genetically uniform varieties having displaced the indigenous varieties worldwide. Indigenous varieties are genetically diverse, adapted to local conditions and resistant to disease; and if these varieties were still planted all over the world instead of the Green Revolution monoculture varieties, we would have nothing to fear from disease pandemics.

Indeed underlying the almost \$200 billion value of US agriculture production is a little known

resource, the gene banks around the world. The report [1], released at a congressional briefing in Washington 28 February 2005, noted that the collections held in gene banks "represent the historic and current diversity of agriculture, without which farming in the U.S. and around the world would stagnate and flounder."

The same alarm was raised again in May 2006. The world's crop gene banks are in crisis, said a meeting of maize researchers in Texococo, Mexico [2]. At least half the seed stocks are unable to germinate because of incorrect storage. Maize grows in 160 countries. Government and international centres hold more than 250 000 varieties of maize, but much of the stock is useless, said Cary Fowler of the Global Crop Diversity Trust in Rome, Italy. Germination rates are falling drastically and useful genetic traits are lost as a result. Suketoshi Taba, head of the international maize gene bank CIMMYT based in Mexico, says less than half the maize seeds held in store around the world were able to germinate.

At the World Food Day symposium on 19 October 2004, United Nations Food and Agriculture Organisation (FAO) Director-General Jacques Diouf said that global efforts to conserve plants and animals in gene banks, botanical gardens and zoos are vital to maintaining global biodiversity and promoting food security worldwide [3]. In fact, the theme of the 24th annual World Food Day was "Biodiversity for Food Security".

Worldwide, there are nearly 5.4 million crop samples in 1 470 gene banks [4]. These are important repositories for conserving seeds and germ plasm, as agricultural biodiversity has been severely eroded under industrial monoculture practised over the latter half of the last century [3] (see Box 6.1). Lack of biodiversity leaves major crops vulnerable to disease, causing famines and starvation. The Irish Potato famine in the 1830s happened because the *Phytophthora* potato blight destroyed the entire crop, as the farmers grew

Box 6.1

Loss of agricultural biodiversity from industrial monoculture

FAO estimates that about 75 percent of the genetic diversity of agricultural crops had been lost during the last century of industrial monoculture. Farmers in the United States grew more than 7 000 varieties of apples in the 1800s; by the end of the 1900s, all but 300 were extinct. In 1949, farmers in China grew 10 000 varieties of wheat; by the 1970s, they grew just 1000. Similar losses of maize varieties have occurred in Mexico and of rice varieties in India. Of 6 500 animal breeds known today, almost one third are threatened or already extinct.

only one variety, and there was no genetic diversity in seed banks or elsewhere to fall back on. Gene banks also play a vital role in maximizing the use of wild and cultivated varieties in crop improvement through selective breeding.

Gene banks have been in major trouble for some years; there simply is not enough money for gene banks to fulfil even their basic conservation role, let alone the other role of maximising the use of wild and domesticated varieties for crop breeding and improvement.

When dried and kept cold, some seeds will last for 30 years or longer. Others have to be grown out regularly and harvested to keep seeds fresh and alive. Tubers, roots and cuttings for plants can be kept in test tubes, usually as tissue culture, and periodically regenerated. All these cannot be done without money. Without proper care, existing seed stocks will eventually lose viability.

Jeff Waage of Imperial College's department of agricultural sciences in London, UK, had earlier reported to the United Nations World Summit on Sustainable Development in August 2002 [4], that although the number of plant samples held in crop diversity collections has increased by 65 percent, gene bank budgets have been cut back in 25 percent of the countries, and remained the same in another 35 percent.

Waage's report said that one in 12 of the world's 250 000 species of flowering plants are likely to disappear before 2025. A chief culprit is

modern agriculture, particularly when forests are cleared to create farmland. "Among the losses are the wild relatives of domesticated plants with as yet untapped potential". These include wheat, soya beans, tomatoes, coffee and grapes

To add to the trouble, war in developing countries had destroyed some vital centres, others have their electricity cut off, so rare seeds are not kept in cool conditions required. Rwanda, Burundi, Somalia and Romania have all lost their genebanks. Albania, Fiji and Nigeria have lost part of their collections.

In response to the crisis in gene banks, the Global Crop Diversity Trust was launched at the World Summit for Sustainable Development in 2002 (Box 6.2).

Genetic engineering the new threat

A new threat to gene banks has surfaced in the events surrounding the forced merger in 2002 of Italy's gene bank in Bari - among the world's ten largest - with much smaller centres involved in genetic modification of crop plants [5].

Although by far the biggest institution in the merger, its director since 1982, Pietro Perrino, was sidelined in the competition for the directorship of the merged institute, which went instead, to a professor in Naples. Perrino was downgraded to "manager" of Bari's germplasm collection of 84 000 accessions. But right from the first, it was obvious that the new director has little or no

Box 6.2

Global Crop Diversity Trust and Doomsday Seed Vault

The Global Crop Diversity Trust was set up in 2002 at the World Summit for Sustainable Development as a type 2 (public-private partnership) involving the FAO and the 15 "Future Harvest Centres" of the Consultative Group on International Agricultural Research (CGIAR) [6, 7]. It hoped to raise the US\$260 million required to protect the world's most important crop species; so far (November 2007) only \$136 million has been committed. On 26 February 2008, a 'doomsday vault' was inaugurated in the frozen Arctic of Longyearbyen, Norway, some 1 000 km from the North Pole [8]. This vault is spacious enough to hold up to 4.5 million batches of seeds from all known varieties of the planet's main food crops, so that if they disappear from their natural environment or are obliterated by major disasters, it will be possible to re-establish the plants.



Diversity of wheat from the Bari gene bank



Local beans from Nusa Tenggara, Indonesia

interest in preserving the collection. Things came to a head when the cooling system broke down and the director refused to have it repaired. In desperation, Perrino resorted to the law court to have the collection placed under his custody in order to have the cooling system repaired. But damages to the collection may have already occurred.

Perrino and his supporters are convinced that the new director and the "pro-GM lobby" are not at all interested in conserving the collection, but are using it as a pretext for getting research funding for genetic modification. More than that, Perrino and his supporters suspect that the pro-GM lobby and the GM giants really would like to see the collection destroyed.

This may sound far-fetched until one gets inside the genetic engineer's mindset. To a genetic engineer, DNA is all. Once a genome sequence is known and deposited in a database, and the DNA of the plant genome deposited in a DNA biobank, then the seed or plant is really of little or no interest. After all, DNA sequences of any gene can easily be synthesized in the laboratory and used to transform existing crop plants to make any desired GM variety, be it herbicide tolerance, insect resistance, salt or drought tolerance, improved nutritional properties, increase in yield, etc., at least in theory. That is precisely the same mentality that motivates "gene-hunting" of indigenous tribes threatened with extinction, so as to preserve their DNA before they become extinct, "for the good of humanity".

Unfortunately, we can no more resurrect a plant from its DNA than reconstruct an extinct indigenous tribe with its distinctive language, knowledge and culture that constitute an entire way of life.

This exclusive emphasis on DNA is misplaced even for genetic engineers, especially those using marker-assisted selective breeding on existing lines to enable them to identify useful traits [9]. The genetic markers can be identified through screening the DNA; but the plants themselves will still be needed for cross breeding.

An additional disincentive for proponents of

GM to preserve germ plasm in seed banks is that they are considered the natural heritage of the earth, if not of the human species, and cannot be patented for commercial exploitation if there is no genetic modification or gene isolation involved (see Box 6.3). So, as far as agribusiness is concerned, they are of no commercial value, or indeed of negative commercial value, as seed or germ plasm collection allows farmers to do their own selective breeding for improving crops and livestock, instead of having to purchase patented seeds from the companies and pay royalties [10]. And that's precisely the reason why gene banks are important, particularly if farmers can get ready access to their collections (see below) to enable them to recover the indigenous varieties displaced by Green Revolution monoculture seeds for sustainable food production that could set them free from the corporate serfdom effectively imposed through the package of patented GM seeds and proprietary herbicides.

In situ conservation for food sovereignty

Apart from the *ex situ* conservation, *in situ* conservation - maintaining biodiversity on farms and in nature - is equally important, if not more so, for the farmers' food sovereignty that could truly guarantee food security (see Chapter 2).

Jacque Diouf himself has stressed the importance of *in situ* conservation [3]. "The responsibility for conserving agrobiodiversity on farms in a great part of the world usually belongs to women farmers who traditionally harvest and conserve crop seeds from season to season. This local agrobiodiversity is particularly important for the resilience of farming systems and communities in emergencies or humanitarian crises, such as those that affected more than 45 million people last year." As most of the earth's genetic diversity is found in the poor countries in the developing world; "it is imperative that those most responsible for its development and its preservation - the indigenous people who maintain the farms, the herds, the forests and the fishing areas - are both respected and rewarded for their efforts."

In situ conservation and seed saving by local communities themselves is the key to recovering and safeguarding local agricultural biodiversity for genuinely sustainable food systems that involves local production and consumption, and restores self-sufficiency and autonomy to farmers and the local communities.

"There used to be many local variety seeds not only for food crops such as rice and corn, but also for beans/legumes and fruit trees," says Hira Jhamtani of Konphalindo, Indonesia, a public interest organisation involved in promoting sustainable agriculture. "The problem is that the knowledge is dying with the old farmers, and the younger generation has no comprehensive knowledge on seed conservation, nor do they seem to be interested. This is where scientists can play a role in documenting local seed varieties and reviving seed breeding among the younger generations based and rooted in local knowledge. The local know-how still exists in many places in Indonesia (and also the Philippines), the question

is how to regenerate the biodiverse agricultural-base and revitalise this knowledge through community based activities."

Neth Dano, associate of Third World Network in the Philippines, who has worked with local communities to develop sustainable agriculture for many years, is less than happy about a blanket call to increase funding for gene banks. "The gene bank/ex situ strategy should not be seen as a stand-alone genetic conservation strategy but should complement the in-situ/on-farm strategies of communities, institutions and civil society," says Dano, "This would require gene bank scientists working closely with farmers and indigenous peoples in seeds conservation on farm. Increase funding for gene banks should be tied to increased funding for in-situ/on-farm conservation and utilization will ensure that the gene banks will not just conserve genetic resources for corporate agriculture, but first and foremost for world food security and the livelihood of those who have nurtured and are dependent on these genetic resources.

"We also have to take note that there are many cases when the *ex situ* conservation is not relevant *at all*, as in *the case of* the Least Developed Countries which cannot even afford to pay for electricity to keep the gene banks running after these have been built through grants or *even* loans that the future generation will have to pay." Dano adds.

She also points out that even if most or all of the collections in the CGIAR genebanks are not patented, as they are "common heritage of mankind", they remain inaccessible to farmers especially if traditional breeds have already been lost. Gene banks should make every effort to ensure that their collections are accessible to the farmers and indigenous peoples who need them, as most of the materials were collected by scientists from farming and indigenous communities in the first place. There must be concrete mechanisms to inform farmers and to facilitate farmers' access to these materials.

Seed-saving for food sovereignty

Seed saving is an important activity that does not have to wait for massive funding, and many local communities have already started to do just that, to make sure they conserve what they still have, and not to depend on gene banks.

Gene banks should make every effort to ensure that their collections are accessible to the farmers and indigenous peoples who need them, as most of the materials were collected by scientists from farming and indigenous communities in the first place

For example, the Henry Doubleday Research Association in the UK with 30 000 members are a major seed saver for organic gardening and farming, although it is not a gene bank. Its Heritage Seed Library conserves and makes available to members European vegetable varieties that are not widely available. Currently, 700 accessions of open-pollinated varieties are held, and about 200 are in its Seed Catalogue sent free to members

(<http://www.hdra.org.uk/hsl/index.htm>).

Navdanya ("Nine seeds") started by Dr. Vandana Shiva of the Research Foundation for Science, Technology and Ecology in India is active not only in seed saving but also in revitalising indigenous knowledge and culture, in creating awareness on the hazards of genetic engineering, and in defending people's knowledge from biopiracy and people's food rights in the face of globalisation. It has its own seed bank and organic farm over an area of 20 acres in Uttranchal, north India (<http://www.navdanya.org/>).

In Ireland, Anita Hayes founded the Irish Seed Savers Association (ISSA) in 1991 in her own home and garden. But with a core of willing helpers and seed donations, and financial aid from government bodies and many generous funders, the ISSA took off. It now has a large collection of Irish fruits, cereals and vegetables (<http://www.irishseedsavers.ie/>).

Box 6.3

International Treaty on Plant Genetic Resources for Food and Agriculture.

This treaty is the outcome of the International Undertaking (IU) on Plant Genetic Resources for Food and Agriculture adopted by the FAO conference in 1983. Starting in 1996, the IU was revised through negotiations to make it compatible with the Convention on Biological Diversity (CBD), and renamed the International Treaty (IT). Negotiations were finalized in November 2001, and the IT was hailed by FAO Director-General Jacques Diouf [3] as "a triumph for the indigenous farmers, herders, forest dwellers and fishing communities of the world." It establishes a multilateral system of access and benefit sharing to ensure that plant genetic resources of the greatest importance to food security are readily available for use now and in the future, and that any benefits are shared with the countries in which they originated. It also establishes a mechanism to ensure that researchers worldwide have access to those resources. Critics note however, that it does not go far enough in protecting our common heritage from commercial exploitation and patenting [11]. The United States is a signatory to the treaty, which entered into force in June 2004.

- 7 -

Organic Boom Around the World Challenges of Certification and Corporate Makeover

Certification is costly and complex and the organic food system is being taken over by food corporations that undermine its traditional values



Organic box scheme
Riverford Farm, UK

Organic agriculture increasing rapidly in many countries

Organic production is increasing rapidly across the world [2]. Australia remains top of the world with more than 11.8 m ha of certified organic farmland, Argentina is second with 3.1 m ha, China comes third with 2.3 m ha and the US is fourth with 1.6 m ha.

The most significant portion of the global organic surface area is in Oceania (39 percent), followed by Europe (23 percent) and Latin America (19 percent). In terms of certified area as a proportion of all arable land, Austria is top with more than 14 percent. The most notable growth over the past year was in the US at more than 400 000 ha. Italy has increased more than 111 000 ha, and Poland, 85 000 ha.

Certification and accreditation an obstacle to growth

One major obstacle to growth in the organic sector is certification and accreditation [1]. Products are labelled organic based on certification that they have been grown, handled and processed in accordance with organic standards. These certifications are generally provided by third parties, which are then accredited to an overlying organization, which may be national, international, governmental or non-governmental.

Certification systems and standards were initially developed by farmers and farmer organizations, and shaped by local conditions and markets. Hence the roots of certification contained both diversity and local control, even though there was a lot in common. As organic agriculture expanded, more specialized certifying organizations have been created, many of these becoming larger in size and scope.

IFOAM has commented on its website that, "The growth of organic agriculture and markets during the last decade has been accompanied by a rapid growth in the number and complexity of private sector standards followed by the burgeoning of government organic regulations.

What is organic agriculture?

The WHO/FAO/Codex Alimentarius Commission defines organic agriculture as a holistic production management system that promotes and enhances agro-ecosystem health, including biodiversity, biological cycles and soil biological activity; that emphasizes management practices in preference to off-farm inputs, using, where possible, agronomic, biological and mechanical methods, as opposed to synthetic materials.

IFOAM (International Federation of Organic Agriculture Movements) and other advocates give similar definitions [1]. Organic agriculture currently covers 31 million hectares (ha) of cultivated land worldwide [2] plus 62 million ha of certified wild harvested areas. The global market for organic products reached 25.5 billion Euros in 2005, with the vast majority of products consumed in North America and Europe.

Though the purpose of certification was to foster confidence of buyers and enhance trade, the plethora of certification requirements and regulations is now considered to be an obstacle for the continuous and rapid development of the organic sector."

For example, there are virtually no mutual equivalence agreements between countries on organic standards. Efforts to establish equivalence among the many regulatory systems have been led by IFOAM together with FAO, the International Trade Centre of the United Nations Conference on Trade and Development, the European Union. There is consensus about standards on major issues - such as the clear exclusion of GMOs - though debate continues on others, such as the use of food additives and processing aids.

As the national governments in Europe and North America institutionalise certification and become involved as accrediting organizations, they may become "gatekeepers" controlling access to these largest markets. It increases the cost and complexity of certification to the point that small-scale farmers may be excluded.

Price premium is also an obstacle, resulting primarily from the high costs of labour, far greater than money saved in reduced inputs such as pesticides and chemical fertilizers (though this price differential is set to become smaller as the price of fossil fuels continue to soar). The higher return to farmers is integral to the future of organic agriculture, and this has been proven in again and again (see many chapters in this volume).

Concentration of production, processing and distribution

As the organic market expands, the traditional open, fragmented structure of organic agriculture is becoming more concentrated, mimicking the conventional agricultural produce market in mergers and acquisitions, and a trend towards concentration of production, processing and distribution. This has had several negative effects: accelerated loss of genetic diversity, reduced innovation, less responsiveness to consumer and social interests, and fewer decision-makers in the industry [1].

Food industry giants - Archer Daniels Midland, Cadbury, Schweppes, Coca Cola, ConAgra, Dean Foods Dole, Gernal Mills, Groupe Danone, H.J. Heinz, Kellogg, Mars, Parmalat Fianziano, Draft, Sara Lee and Tyson Foods - have been buying up successful organic firms. Novartis has "Tender Harvest", a leading organic baby food brand, produced by its subsidiary Gerber.

The US dairy industry, whether conventional or organic, is highly concentrated. One company, Horizon Organic Dairy, processes and distributes almost 70 percent of the organic milk in the US. Horizon was founded in 1992 to market organic yoghurt, but soon expanded to a complete line of dairy products. Today, it is the largest single US organic brand by sales (\$187million) and by distribution, even with a 30 to 50 percent price premium. The company has also gained market share through acquisition of many local and regional dairies. Horizon has been buying dairy

companies and brands in Britain (Meadow Farms Ltd., Organic Matters Ltd., and Rachel's Organic) and has made a licensing agreement with a Japanese organic milk producer.

Horizon cut contractually-promised premiums to farmer after it bought out The Organic Cow of Vermont, which decreased farmers' incomes by as much as \$15 000 per family, even as the company reported a 200 percent increase in profits on net sales of \$160 million. Horizon was since acquired by Dean Foods, the largest fluid milk producer in the US and one of the five largest in the world with \$10 billion in annual sales.

Farmers find it hard to deal with big companies, as big companies find it too troublesome to deal with individual farmers.

"The best guarantee that your food will be produced according to environmental and social principles is to meet the people who grow it"

In the US, half of retail organic sales go through the 'core channel', natural food retailers, including natural supermarket chains, independent retailers, and cooperatives, as well as direct sales. Natural foods supermarkets and supermarket chains (the "supernaturals") are the most rapidly growing part of this category. The largest chain by sales in the US and in the world is Whole Food Market, with 140 stores and \$3.7 billion sales. The second is Trader Joe's, owned by German retail giant Albrecht Discounts. Trader Joe's has 200 much smaller stores in 17 states, with annual sales of £1.9 billion. The third largest chain is Wild Oats, with 102 stores in US and Canada and an estimated \$946 million in sales. Over the past several years, Whole Foods and Wild Oats have acquired almost all other retail chains of meaningful size in the core channel.

Farmers markets, community-supported agriculture (CSA) establishments and food co-ops remain important outlets for organic foods. There are 2 651 farmers markets, over 1 000 CSAs and 300 food co-ops selling organic foods. Cooperative Development Services, which provides consulting on the food cooperative business, estimates total US co-op sales at \$750 million annually (2003). Direct sales, farmers markets and CSAs account for 3 percent of all sales in the US, health and natural products stores for 48 percent and mass market outlets for 49 percent.

Jason Mark wrote in the San Francisco Chronicle [3]: "the best guarantee that your food will be produced according to environmental and social principles is to meet the people who grow it. Support your local farmers' market and become friendly with the vendors there. Or get a subscription with a Community Support Agriculture program, in which you get weekly food deliveries from a specific farm. Those outlets represent the original ethic of the organic food movement."

A more radical solution is to opt for a special comprehensive labelling that informs the consumer directly, by-passing the complex certification scheme and enabling consumers to support their local regional produce (see next Chapter).

- 8 -

The Real Costs of Food Miles

Behind the statistics is a globalised food trade that's exacerbating poverty and climate change

Local food systems must be supported if we are to feed the world



Food miles an indicator of sustainability

Food transported across the world burns up a lot of fossil fuels and contributes to global warming. "Food miles" - the total distance in miles the food item is transported from field to plate - has become accepted as a convenient indicator of sustainability, and has led to a general movement towards local production and local consumption in order to minimize them. This raises fundamental questions about the sustainability of the globalised food trade and the increasing concentration of the food supply chain and distribution in the hands of fewer and fewer transnational corporations.

UK's Department of the Environment, Food and Rural Affairs (Defra) commissioned a report to look into food miles, which was published in July 2005 [1].

Food transport has significant and growing impacts

The Report found unsurprisingly that since 1978, the annual amount of food moved by heavy goods vehicles (HGVs) in the UK has increased by 23 percent, with the average distance for each trip also up by 50 percent.

Food transport accounted for an estimated 30 billion vehicle kilometres in 2002 of which 82 percent were in the UK; it accounted for 25

percent of all HGV kilometres in the UK. It produced 19 million tonnes of CO₂, of which 10 million tonnes were emitted in the UK; almost all from road transport. This represented 1.8 percent of the total annual UK CO₂ emissions, and 8.7 percent of the total emissions of the UK road sector.

Transport of food by air had the highest CO₂ emissions per tonne of food, and is the fastest growing mode. Although airfreight of food accounts for only 1 percent of food transport in terms of tonne-kilometres, and 0.1 percent in terms of vehicle-kilometres, it produced 11 percent of the food transport CO₂ equivalent emissions.

But what are the real costs of food transport?

The real costs of food transport

The direct social, environmental, and economic costs of food transport were estimated at over £9 billion each year, and dominated by congestion. The social cost of congestion was estimated at £5 billion. Accidents led to social costs of £2 billion per year, and greenhouse gas emissions, air pollution, noise and infrastructure cost a further £2 billion. The Report was in no doubt that "The total costs are very significant compared with the gross value of the agricultural sector of £6.4 billion, and the food and drink manufacturing sector of £19.8 billion."

In other words, the £26.2 billion agriculture and food and drink industry sectors cost the taxpayer £9 billion (34 percent of their gross value) each year. This is an underestimate, as the report stressed that impacts due to air transport have not been included.

Causes for the increase of food miles correctly identified

The Report correctly identified the five most striking changes in the UK food production and supply chain in the last fifty years that have greatly increased food transport.

- Globalisation of the food industry with increased imports and exports and ever wider sourcing of food within the UK and abroad
- Concentration of the food supply base into fewer, larger suppliers, partly to meet demand for bulk year-round supplies of uniform produce

- Major changes in delivery patterns with most goods now routed through supermarket regional distribution centres using larger HGVs
- Centralized and concentrated sales in supermarkets where a weekly shop by car has replaced frequent pedestrian shop visits

The statistics, dire as they are, only hint at the scale of the real problem both at home and abroad, where identical produce is swapped across Europe and cash crops are flown in from the Third World for the furtherance of 'free trade', promoted by the World Trade Organization and other free trade agreements (see Chapter 4).

The issue of airfreight has entered the organic food and farming debate in 2007.

Is airfreight organic food really organic?

The organic market grew by 25 percent in the UK to £1.97 bn in the year 2006-2007, but more than 30 percent of organic products is imported, some even flown in from sub-Saharan Africa [2]. Does that make sense in the cost in CO₂ emissions?

Especially when so many hungry people there are too poor to buy the food grown in their own countries?

After months of consultation, the Soil Association, which certifies 70 percent of organic food in the UK, published its recommendations based on more than 200 written submissions. The details of the proposal will be up for further consultation in 2008, and new certification rules are expected to come into effect January 2009.

The impact on the organic market may be relatively small, as less than one percent of organic imports enter the UK by air. But 80 percent of airfreight organics comes from low or lower-middle income countries.

The Soil Association is proposing [3] that any airfreight products should meet its own ethical trading standards or the Fairtrade Foundation's standards by 2011. It wants businesses dependent on airfreight organic products to develop initiatives to reduce airfreight, and is encouraging people and businesses to be less reliant on fossil fuels for their livelihood.

The proposal to have ethical trade standards mandatory in its organic certification is new, as they have been voluntary so far. The standards entail "fair and ethical tradition relationships", "socially responsible practices" and "fair and ethical employment" throughout the entire organic food chain, from producer to retailer and in both developing and developed countries.

The association is also looking into reliably and fairly assessing the full carbon footprint of organic products, and wants "all organic products to have a minimal or even mitigating contribution to climate change." It is reviewing standards for heated glasshouse production and actively encouraging people to eat less meat.

The Soil Association's discussion document set out other options for reducing carbon emissions including the possibility of labelling organic food products with the number of air miles they have travelled, or a programme whereby the carbon produced by airfreight is offset.

Mixed reactions

Oxfam welcomed the emphasis of the new proposals on fair trade standard, but warned that change in policy should be phased in over a suitable period to minimize negative impacts on the most vulnerable producers and to provide support for them [4]. Oxfam spokesperson Duncan Green pointed out that if everyone in the UK replaced one 100 W light bulb with a low energy equivalent, it would reduce UK's CO₂ emissions by five times the amount that would result from not buying airfreight fresh fruit and vegetables from sub-Saharan Africa. "It is essential that our responses to climate change should not harm the people who are least responsible for the environmental damage in the first place."

The International Trade Centre (ITC) is altogether unconvinced. It says that organic exporters now face new costs to enter the UK, and poor African farmers will therefore find it harder to enter the markets. Moreover, the ITC claimed that most of the food grown in the UK and continental Europe produce more greenhouse gases than organic exports air-freighted by poor African farmers [2]. ITC trade and development expert Alexander Kasterine said, "Food transport has nothing to do with working conditions of farm workers, and only a small proportion of these exporters are currently using fair trade or ethical trade standards."

Cost of organic certification prohibitive

UK's Minister for Trade and Development Gareth Thomas said he was "disappointed" with the Soil Association proposal to withdraw certification from airfreight products that are not additionally certified to ethical trade standards [6]. He was worried about the costs of additional certification, pointing out that, "certifying new products can take from six months to several years and costs between tens and hundreds of thousands of Euros."

He also said that airfreight ban "does little to solve climate change", as less than one tenth of one percent of UK greenhouse gas emission come from airfreight fruit and vegetables from Africa; and driving six and a half miles to buy from a shop emits more carbon than flying a pack of Kenyan green beans to the UK. "There can be no denying that food transport has an environmental and social cost, but most of this (about 85%) comes from UK roads," he said.

The UK government is encouraging more efficient distribution within the food and drink sector, and proposed that the food industry trade bodies look into achieving a 20 percent reduction in the social costs of transporting food in the UK by 2012.

The food and drink manufacturing, food retail and catering sectors are currently responsible for approximately 4 percent of UK's annual greenhouse gas emissions of about 26 Mt CO₂e (CO₂ equivalent) per year [6]. The food chain as a whole from farm to plate, which includes transport and distribution, domestic energy use from storage and cooking, is around 111 Mt, or approx 17 percent of UK's emissions.

The Food Industry Sustainability Strategy (FISS) published in April 2006 [5], is considering a 3.5 percent reduction a year over 5 years from a 2006 baseline, by improving the efficiency of product manufacturing, and by reducing waste.

The direct social, environmental, and economic costs of food transport were estimated at over £9 billion each year

Global trade and poverty

But it is trade that's uppermost in the mind of the Minister of Trade and Development. British shoppers spend over £1 million a day on imported fruit and vegetables from Africa; and in addition to the very small minority of organic farmers, almost a million conventional farmers and their families depend on airfreight fruit and vegetables from Africa to the UK.

"Trade is fundamental to development." He said [7], "To beat world poverty, it is essential that economic growth is encouraged in the world's poorest countries. They must be able to trade on the global market, exporting their goods freely and getting a fair price for them."

Unfortunately, it is precisely a fair price that the poor farmers everywhere cannot get without mandatory ethical trade standards. And it is precisely this misplaced emphasis on export trade in the aftermath of the Green Revolution that has resulted in poverty and hunger (see Chapters 2 and 4).

India, the home of the Green Revolution in Asia, is a major food exporter, and its 26 m ton grain surplus in 2006 could feed the 320 million of it population that go to bed hungry. But the starving villagers are too poor to buy the food produced at their doorstep. India is also caught in a worsening epidemic of farmers' suicide largely as the result of subsidized dumping in the global 'free-trade' market. Debt-ridden farmers are caught in a downward spiral of rising costs of fertilizers and pesticides and diminishing income due to plummeting commodity prices, falling yields from unsustainable cultivation practices and recently, massive crop failures for those who have been deceived into planting GM crops. An estimated 100 000 farmers have taken their own lives between 1993 and 2003 and the introduction GM crops has escalated the suicides to 16 000 a year.

The transparent food label containing everything that the organic consumer would want to know as an alternative to organic certification

Only organic agriculture that protects local food systems can feed the world

Organic agriculture can feed the world, the scientists say (see Chapter 9). But it is becoming especially clear that *only* the right kind of organic agriculture can feed the world, an organic agriculture that supports local production and local consumption, and protects the livelihood of farmers (Chapter 2).

World trade in food has more than doubled from US\$ 209 billion in 1985 to US\$ 463 billion in 1996, and projected to reach US\$ 625 billion in 2005 [8]. Despite that, most of the world's food is

still grown, collected and harvested by over a billion small farmers, pastoralists and fisherfolk; and is sold, processed and consumed locally, with many more people deriving incomes and livelihoods from different links in the food chain, such as millers, butchers, carpenters, iron workers and mechanics, local milk processors, bakers, small shopkeepers, etc [9]. Even in the affluent countries such as the USA and UK, there is strong evidence that local food systems generate many jobs and sustain small and medium-sized enterprises. For example, the establishment of 25 000 out of town large chain-retailers in the UK by 1992 closed down roughly 280 000 independent shops in villages and high streets. When 235 000 US small and medium scale farms were squeezed out by market competition in the mid-1980s, about 60 000 other local rural businesses also closed.

There is indeed growing concern over ethical trade standards and carbon footprint in organic certification. Consumers are buying into fair trade products from Third World countries, but they generally also prefer locally produced fresh fruits and vegetables, not only because that cuts down on carbon emissions and helps mitigate climate change, but also because it supports local farmers whose farms they can visit at any time.

The producers' label

Conscientious consumers are demanding more information about the food they eat, especially as different certification schemes are not all the same.

Mario Pianesi, founder of the highly influential macrobiotic association in Italy, Un Punto Macrobiotico (UPM) (see Box 8.1), has initiated just the kind of transparent, comprehensive label that gives all the information the most discerning organic consumer might want.

Pianesi's label has information on the entire food chain from farm to shop shelf. It tells you the location of the farm that grows the food, the area and amount harvested, the year of the harvest, the number of people employed, and the specifics of the farming method, such as the origin of the seed, how the sowing is done, what kind of organic fertilizer used (if any), energy used, whether irrigated and amount of water used, weed control, and details of processing (if any) (see photo).

The label is already in use, and on natural non-food products as well, though not all information is available or mandatory. The advantage is that it is not a certification scheme, and hence has no certification cost attached. But the producer of the item can be taken to court if something printed on the label turns out not to be true. Consumers buy it because they have confidence in the brand and approve of the labelling scheme. This scheme is therefore most likely to work in the local community or region, and that's good enough for consumers and farmers who support the ideal organic food system.

Pianesi is trying to get this label accepted by the Italian Senate, where the majority of the representatives are in favour. But he has yet to convince most of the Italian producers.



Pianesi's label on preserves

Box 8.1 Mario Pianesi and Un Punto Macrobiotico

Mario Pianesi founded the association Un Punto Macrobiotico (UPM) in 1980. With his mother from Montenegro and his father from the Marche region, Pianesi appreciated the positive sides of the Mediterranean cuisine.

At the age of 26, he took evening courses in nutrition. When he read the book, *Zen Macrobiotics* by Georges Ohsawa, he learned about the ancient Chinese theories of Yin and Yang and the five Transformations. He spent the next 10 years studying these ideas, trying to confirm the application of the theories to various branches of science, and then promoted them within the UPM centres. After that, he began to organize public conferences that have continued uninterrupted to the present day. He has given different courses for doctors, teaching diagnosis and nutrition according to the two ancient Chinese theories, and he was among the first to become acquainted with iridology, the diagnosis of illnesses from the appearance of the iris.

In seeking to unite traditional Chinese and modern science, as president of UPM, he organized a series of conferences on different themes, starting with "Macrobiotics and Science" in 1995, "Culture" in 2000, "From Ancient Chinese Theory to the Sustainable Pianesian Development" in 2002, "Rice: Fundamental Food for Human Health" in 2004, and "Environment, Agriculture, Nutrition, Health, Economy" in 2006 to coincide with the World Food Day. All these conferences still take place annually.

In 2001, UPM organized its first initiative at the Senate of the Italian Republic, presenting the transparent label designed by Pianesi, and approved so far by 88 senators.

In the same year the Association launched the "Ma-Pi Diabetes Project" in Asia, South America and North Africa, through which the effectiveness of Ma-Pi macrobiotic diets has been proven on patients affected with diabetes.

The first documented scientific results of this project were obtained in Cuba [8]. Today, the "Ma-Pi Diabetes Project" has expanded to other countries.

For his work in the service of the environment, agriculture and health, Pianesi has received recognition from various local, provincial and regional groups, and from the Society of Natural Science in Tunisia. In 2006 he received the award of "Best work in diet therapy" from the Medical Diet congress in Dijan, China; and in 2007, he was given the degree "Honoris Causa" from the Academy of Science in Mongolia. In 2005 he was asked to serve on the UNESCO Scientific Committee for the Decade of Education for Sustainable Development.

Through the development and growth of UPM, the Marche region in Italy came to have the highest concentration of macrobiotic centres in the world, with stores, restaurants, food laboratories, factories producing natural clothing, natural footwear, natural furnishings, natural paint and construction products.

In UPM stores and restaurants, foods products are sold that adhere to strict standards and bear the label designed by Pianesi, which is also now being used on non-food products.

Pianesi directly stimulated the founding of the first organic farming cooperative in Italy in 1975, and in 1980, began to recover seeds of plants that have been abandoned in favour of hybrid seeds or GMOs. Since then, he has continued his research towards natural agriculture, proposing an original agricultural model of "policultura pianesiana" (Pianesian polyculture).

Starting with seeds reproduced in the fields, obtained directly from farmers, the plants are allowed to revert as much as possible to their wild state, cereals, beans and vegetables are grown in the middle of fruit or other trees spaced at about 5 to 6 metres, in combination with hedges to produce a natural, balanced environment.

With this polyculture system, farmers have reported an increase in production and a significant reduction in costs, in addition to substantial positive effects on land previously turned alkaline from monoculture and intensive treatment with chemicals, achieving a pH reduction from 6.5 to 5.5 in just a few years.

From the UPM Secretariat

Overall Benefits

- 9 -

Scientists Find Organic Agriculture Can Feed the World & More

Comprehensive study gives the lie to claims that organic agriculture cannot feed the world because it gives low yields and there is insufficient organic fertilizer

Organic agriculture gives higher yields overall for the world



Scientists refute common misconceptions about organic agriculture

Two usual objections are levelled against the proposal that organic agriculture can feed the world. Organic agriculture, opponents claim, gives low yields, and there isn't enough organic fertilizer to boost yields substantially.

A team of scientists led by Catherine Badgley at the University of Michigan Ann Arbor in the United States has now refuted those common misconceptions about organic agriculture. Organic agriculture gives yields roughly comparable to conventional agriculture in developed countries

and much higher yields in developing countries; and more than enough nitrogen can be fixed in the soil by using green manure alone [1].

The research team compared yields of organic and conventional agriculture (including low-intensive food production) in 293 examples, and estimated the average yield ratio (organic versus non-organic) of different food categories for the developed and the developing world. With the average yield ratios, they modelled the global food supply that could be grown organically in the current agricultural land base. The results indicate that organic methods could produce enough food to sustain the current human population, and potentially an even larger population, without

increasing the agricultural land base.

They also estimated the amount of nitrogen potentially available from nitrogen fixation by legumes as cover crops. Data from temperate and tropical agro-ecosystems suggest that they could fix enough nitrogen to replace *all* of the synthetic fertilizer currently in use.

The report concluded: "These results indicate that organic agriculture has the potential to contribute quite substantially to the global food supply, while reducing the detrimental environmental impacts of conventional agriculture."

Wide variety of organic agriculture

The organic agriculture examples reviewed by the Michigan University team cover a wide spectrum of farms that are agro-ecological, sustainable or ecological, but not necessarily certified organic. They rely on natural nutrient-cycling processes, exclude or rarely use synthetic pesticides, and sustain or regenerate soil quality. Farming practices include cover crops, manure application, composting, crop rotation, intercropping, and biological pest control.

The 293 studies reviewed consist of 160 that compared organic with conventional methods and 133 cases comparing organic with low-intensive methods. Most studies are from the peer-reviewed published literature, a minority from conference proceedings, technical reports or website of an agricultural research station. They range from a single growing season to over 20 years. Some examples are based on yields before and after conversion to organic in the same farm.

To estimate global food supply from organic agriculture, the average ratios of the yields of organic versus non-organic are applied to current food production values minus post harvest losses from the UN Food and Agriculture Organization (FAO) database for 2001.

Yield ratios of organic versus conventional range from about 1.6 to 4.0. The ratio averaged over all foodstuffs for the world is 1.3

Organic yields beat conventional

The yield ratios summarised in Table 9.1 are grouped into 10 categories covering the major plant and animal components of human diets.

As can be seen, the average yields of organic and non-organic produce are about the same in

the developed world, but it is in the developing world - where most food is needed and where farmers can least afford to pay for expensive synthetic fertilizers and pesticides - that the major gains in organic agriculture are most evident. Yield ratios of organic versus conventional range from about 1.6 to 4.0. The ratio averaged over all foodstuffs for the world is 1.3.

Interestingly, this ratio is just about the same as the increase in yields from organic composting compared to chemical fertilizers in the world's largest single comparative study carried out in Ethiopia over the past 10 years (see Chapter 11). This alone suggests that we need to move away from chemical fertilizers in order to better feed the world.

More than enough organic food to feed the world

The team has worked out two models of global food production. Model 1 is conservative, and applies the yield ratios derived from studies in the developed countries to the entire global agricultural land base; Model 2, more realistically, applies the yield ratios determined for the developed and the developing countries back to the respective regions. The calories per capita resulting from the models are estimated by multiplying the average yields by FAO estimates of calorific content in the food category.

The amount of food available in Model 1 is about the same as currently available. The main gain is in reducing energy and fossil fuel intensive inputs, and avoiding all the collateral damages from conventional agriculture. Model 2 results in real gains of 1.3 to 2.9-fold of various foods available in addition.

Both models show that organic agriculture could sustain the current human population. In terms of daily caloric intake, the current world food supply after losses provides 2 786 kcal/per/day. The average requirement for a healthy adult is between 2 200 and 2 500. Model 1 yields 2 641 kcal/day, above the recommended level (94.8 percent of current level). Model 2 yields 4 381 kcal/day, 157.3 percent of what is current available.

Thus, organic production has the potential to support a substantially larger human population than currently exists.

Food Category	(A) World			(B) Developed Countries			(C) Developing Countries		
	N	Av.	S.E.	N	Av.	S.E.	N	Av.	S.E.
Grain products	171	1.312	0.06	69	0.928	0.02	102	1.573	0.09
Starchy Roots	25	1.686	0.27	14	0.891	0.04	11	2.697	0.46
Sugars and Sweeteners	2	1.005	0.02	2	1.005	0.02			
Legumes(pulses)	9	1.522	0.55	7	0.816	0.07	2	3.995	1.68
Oil crops and Veg oils	15	1.078	0.07	13	0.991	0.05	2	1.645	0.00
Vegetables	37	1.084	0.10	31	0.876	0.03	6	2.038	0.44
Fruits excl. wine	7	2.080	0.43	2	0.955	0.04	5	2.530	0.46
All plant foods	266	1.325	0.05	138	0.914	0.02	128	1.736	0.09
Meat and offal	8	0.988	0.03	8	0.988	0.03			
Milk. excl butter	18	1.434	0.24	13	0.949	0.04	5	2.694	0.57
Eggs	1	1.060		1	1.060				
All animal foods	27	1.288	0.16	22	0.968	0.02	5	2.694	0.57
All plant and animal foods	293	1.321	0.05	160	0.922	0.01	133	1.802	0.09

Table 9.1. Yield ratios of organic versus conventional agriculture

More than enough nitrate through biological nitrogen fixation

The main limiting macronutrient for agricultural production is nitrogen in most areas. Nitrogen amendments in organic farming derive from crop residues, animal manure, compost and biologically fixed N from legumes (green manure). In the tropics, legumes grown between plantings of other crops can fix substantial amounts of nitrogen in just 40 to 60 days.

Nitrogen available globally is determined from the rates of N availability or N-fertilizer equivalence reported in 77 studies, 33 for temperate regions and 44 for the tropics, including three from arid regions and 18 paddy rice.

The availability of N in kg/ha is obtained from studies as either 'fertilizer-replacement value' (i.e., the amount of N fertilizer needed to achieve equivalent yields to those obtained using N from cover crops), or calculated as 66 percent of N fixed by a cover crop becoming available for uptake by plants during the growing seasons following the cover crop.

In 2001, the global use of synthetic N fertilizers was 82 Mt. The estimated N fixed by additional legume crops as fertilizer is 140 Mt, based on an average N availability of 102.8 kg N/ha (the average N availability of temperate and tropical regions are 95.1 kg N /ha and 108.6 kg/ha respectively). This is 171 percent of current synthetic N used globally, or 58 Mt more. Even in the US where conventional agriculture predominates, the estimate shows a surplus of available N through the additional use of legume cover crops between normal crops.

In temperate regions, winter cover crops grow well in the autumn after harvest and in early spring before the planting of main food crops. Research at the Rodale Institute (Pennsylvania) showed that red clover and hairy vetch as winter covers in an oat/wheat-corn-soybean rotation with no additional fertilizer achieved yields comparable to those in conventional controls [2] (see Chapter 13). The legume cover crops were grown between main crops every third year as the only source of N fertility. Non-legume winter cover crops are used in other years to maintain soil quality and fertility and to suppress weeds.

In arid and semi-arid tropical regions, where water is limiting between periods of crop production, drought-resistant green manures, such as pigeon peas or groundnuts, can be used to fix N. Using cover crops in arid regions has been shown to increase soil moisture retention.

These estimates of N available do not include other practices for increasing biologically fixed N, such as intercropping, alley cropping with leguminous tress, rotation of livestock with annual crops, and inoculation of soil with free-living N-fixers. In addition, rotation of food-crop legumes, such as pulses, soy, or groundnuts, can contribute as much as 75 kgN/ha to the grains that follow the legumes.

Promises and remaining challenges

The implications of the University of Michigan study are far reaching. The results imply that even

with rather conservative estimates, no additional land area is required to grow enough food to feed the world if we were to switch to organic, and enough biologically available N can be obtained to entirely replace the current use of synthetic N fertilizers.

There are numerous other benefits of switching to organic agriculture not mentioned in the paper that are documented in the Independent Science Panel Report [3] and elsewhere. (see many chapters in this volume).

The largest gains from organic agriculture arise from the savings on the damages to public health and the environment, estimated at more than US \$59.6 billion a year in the United States (see Chapter 13).

Another is the key issue of food security. Findings from the Rodale Institute also confirm that organic management retains more nutrients, organic carbon and moisture in the soil, all of which make organic crops more able to withstand climatic stress. So it is not surprising that while organic yields are comparable to conventional during normal years, they are well ahead in drought years (Chapter 13).

The case for a global shift to organic agriculture has never appeared more compelling and more urgent

There are substantial savings on carbon emissions and fossil fuels to mitigate climate change simply from phasing out pesticides and synthetic fertilizers, not to mention the extra carbon sequestered in organic soils (see Chapter 19).

The study has not even considered all the existing options for renewable energies [4] or systems of farming that turns wastes into food and energy resources, thereby potentially phasing out fossil fuels altogether (see Chapter 34). Nor does it mention the many social, economic, and health benefits from organic agriculture [3] (Chapters 18-24). The case for a global shift to organic agriculture has never appeared more compelling and more urgent.

The Michigan University team see numerous challenges for implementing a comprehensive shift to organic agriculture, however promising it seems. The practice of organic agriculture on a large scale requires support from research institutions dedicated to agro-ecological methods of soil fertility and pest management, a strong extension system and a committed public.

Also needed are strong government commitment and support, and policy changes that favour and encourage a global shift to organic, sustainable agriculture [5] (see Chapters 3 and 4).

Most of all, it is time to put to rest the debate about whether or not organic agriculture can make a substantial contribution to the food supply. We should be debating instead the allocation of resources for research on agro-ecological food production, the creation of incentives for farmers and consumers; and the policies needed at the national and international levels to promote and facilitate the global transition.

- 10 -

FAO Endorses Organic Agriculture

FAO Report says organic farming fights hunger, tackles climate change, good for farmers, consumers and the environment



Gunung Haliman
National Park West
Java Indonesia

FAO favours organic agriculture

The United Nations Food and Agricultural Organisation (FAO) is favourably disposed towards organic agriculture. Its report *Organic Agriculture and Food Security* explicitly states that organic agriculture can address local and global food security challenges [1].

Organic farming is no longer to be considered a niche market within developed countries, but a vibrant commercial agricultural system practised in 120 countries, covering 31 million hectares (ha) of cultivated land plus 62 million ha of certified wild harvested areas (see Chapter 7). The organic market was worth US\$40 billion in 2006, and expected to reach US\$70 billion by 2012.

Nadia Scialabba, an FAO official, defined organic agriculture as: "A holistic production management system that avoids the use of synthetic fertilizers and pesticides, and genetically modified organisms, minimizes pollution of air, soil and water, and optimises the health and productivity of plants, animals and people."

The strongest benefits of organic agriculture, Scialabba said, are its reliance on fossil fuel independent, locally available resources that incur minimal agro-ecological stresses and are cost

effective. She described organic agriculture as a "neo-traditional food system" which combines modern science and indigenous knowledge.

The FAO Report strongly suggests that a worldwide shift to organic agriculture can fight world hunger and at the same time tackle climate change. According to FAO's previous World Food Summit report [2], conventional agriculture, together with deforestation and rangeland burning, are responsible for 30 percent of the CO₂ and 90 percent of nitrous oxide emissions worldwide.

Organic agriculture overcomes paradox of conventional food production systems

The new FAO Report frames the paradox within the conventional food production systems as follows:

- Global food supply is sufficient, but 850 million are undernourished and go hungry
- Use of chemical agricultural inputs is increasing; yet grain productivity is dwindling to seriously low levels
- Costs of agricultural inputs are rising, but commodity costs have been in steady decline over the past five decades.
- Knowledge is increasingly provided through fast information technologies, but nutritionally related diseases are rising
- Industrialised food systems cause deaths through pesticide poisonings and high numbers of farmer have committed suicides, while millions of jobs have been lost in rural areas.

In contrast, organic agriculture offers an alternative food system that improves agricultural performance to better provide access to food, nutritional adequacy, environmental quality, economic efficiency, and social equity. This is crucial if agricultural production in developing countries is to rise by 56 percent by 2030 to meet nutritional needs, as stated in the Report.

Researchers recommend a shift to organic agriculture especially for poor developing countries

Evidence presented to the FAO by the Danish Research Centre for Food and Farming confirm the potential of a new organic farming paradigm to secure more than enough food to feed the world, and with reduced environmental impacts [3]. The

results, using a computer model developed by the Washington DC based Food Policy Research Institute (IFPRI), show that a 50 percent conversion to organic farming in sub-Saharan Africa would not harm food security. Instead, it would help feed the hungry by reducing the need to import subsidised food, and produce a diverse range of certified organic surpluses to be exported at premium profit.

The conversion of global agriculture to organic farming, without converting wild lands for agricultures and using N-fertilizers, would result in a global agricultural supply of 2 640 to 4 380 kcal/day/person. These conclusions came from a research team led by Catherine Badgley at the University of Michigan, based on extensive review of the evidence from both the developed and developing world [4] (see Chapter 9 for details).

The fact that sustainable intensification of organic agriculture could increase production by up to 56 percent is good news, as despite gains in food production and food security in some countries, sub-Saharan Africa produces less food per person than it did 30 years ago; and the number of chronically malnourished people in the region has doubled since 1970, from 96 million to over 200 million in 1996 [2]. This reflects the wider picture that developing countries have registered outright declines in yield between 1972-1992.

In contrast, the current FAO Report presents evidence that organic management systems have doubled yields in arid and degraded soils in Tigray, Ethiopia (see Chapter 11). Alexander Mueller, the FAO assistant director-general, praised the research, and noted that as the effects of climate change are expected to hurt the world's poorest, a shift to organic farming could be beneficial to cope with the rising number of global hungry.

Recommendations arising from the FAO report feed directly into the framework for the Right to Adequate Food and also into the Millenium Development Goal (MDG)1 for reducing hunger and poverty, MDG7 for environmental sustainability, and MDG 8 for global partnerships with emphasis on hidden, acute or chronic hunger.

Environmental and economic benefits of organic agriculture

The Danish researchers [3] suggest that a 50 percent organic conversion by 2020 in the food exporting regions of North America and Europe would have little impact on the availability and prices of food. Converting from chemically intensive farming to organic farming can initially decrease yields, but the adjustment evens out over time and provides numerous non-material benefits such as land improvement.

The FAO Report points to further benefits such as better animal welfare, wildlife protection, avoidance of GMOs and pesticides, more jobs and less energy used. Results from studies carried out by the US Department of Agriculture [5] support the FAO findings; showing that organic crops are worth more than conventional crops on the market, and on average, farmers could net \$50-\$60 more per acre by going organic, even with the highest

transitional costs.

The expansion and intensification of conventional farming is harmful not only to the environment, but also to the very resources essential to farming. Over the past two decades, some 15 million ha of tropical forests are lost each year to provide land for agriculture, and at a tremendous loss of genetic diversity [2]. During the same period, soil erosion and other forms of land degradation cost the world between 5-7 million ha of farming land every year; a further 1.5 million ha are lost to waterlogging and salination, and an additional 30 million ha damaged in other ways.

Organic agriculture has the potential to reverse those trends, and reduce carbon dioxide, nitrous oxide and methane, greenhouse gasses (GHG) that contribute to global warming [1]. Organic agriculture could double soil carbon sequestration in livestock based systems and decrease GHG by 48-60 percent. For example, organic systems have decreased the use of fossil fuels by between 10-70 percent in Europe, and 29-37 percent in the USA.

On organic farms, increasing soil organic matter and microbial biomass is a fundamental principle to support agro-ecosystem stability. Mandatory crop rotation, the use of seeds and breeds that are adapted to local conditions, and the regeneration of functional biodiversity all contribute further to ecological balance.

FAO gives top priority to agricultural production that targets local food needs in local markets, allowing imports only for items not grown locally, and exporting high value produce

Organic networks meet local food demands and benefits farmers

FAO gives top priority to agricultural production that targets local food needs in local markets, allowing imports only for items not grown locally, and exporting high value produce.

In developing countries, food quantity, quality and availability in urban areas are enriched by organic market gardens where local produce is sold to international markets and domestic supermarkets. This reduces dependence on cheap subsidized imports, which are projected to rise to more than 160 million tonnes by the year 2010. For example, a food network in Argentina that covers 3.5 million people reports 70 percent self-sufficiency in vegetable production through organic urban garden networks.

A successful conversion to organic agriculture has occurred in parts of Egypt where scarce or polluted water supplies led to the development of thriving local markets. In China, the awareness of environmental pollution and the need for environmental and health protection resulted in organic-managed land rising from 342 000 ha in 2003 to 978 000 ha in 2005, and increasing local farmers incomes nine-fold.

Cuba is an inspiring example of how food crises can be averted by drastically reducing chemical inputs and relinquishing dependency on fossil fuels [6] (see Chapter 12).

National food security was maintained with

some help from food aid, by re-localizing organic food production, and ensuring food access through food rationing and social safety nets such as food and nutrition surveillance systems. Furthermore, organic urban gardens create a healthy environment for the inhabitants and supply local restaurants, markets and shops with nutritious foods.

As organic produce enters the mainstream, consumers are willing to pay higher prices in exchange for truthful labelling and absorb some of the extra costs of organic agriculture. Demand for organic produce has encouraged countries like Brazil (fast becoming a world leader in organic farming) and India to reconcile their local food demands. The main challenge to international markets is bringing producers together to create value chains of fair trade, informed choice and traceability [1] (see Chapter 8).

And, as Catherine Badgely argues [4], food security depends as much Government policies and market price as it does on yields. Producing organic food has distinct benefits for farmers too. Farmers' rights to local seeds and varieties are strengthened, knowledge sharing is promoted, incomes are raised, production increased, environmental and health protection is improved, natural resources are conserved and outward rural migration is reversed. As organic farming is highly knowledge intensive, the FAO recognises that the organization of organic farmers and growers associations, co-operatives, enterprises, and community groups is crucial to research and development. Farmers converting to organic methods also increase incomes by minimizing chemical inputs and other industrial interventions and thereby break the cycle of indebtedness that has devastated hundreds of thousands of farmers livelihoods (see Chapters 2, 14, 22-24). Ensuring farmers' well-being and increasing national and regional self reliance in food production methods that meet key environmental and animal welfare standards will not only enhance food security, but will also reduce the use of fossil fuel use for food transportation and production [7].

In 2003 the UK Food Standards Agency (FSA) conceded that: "...buying organic is a way to reduce the chances of your food containing these pesticides."

Health benefits of organic agriculture

As the FAO Report points out, organic foods tend to have higher micronutrient content that contributes to better health, lower incidence of non-communicable diseases and boosts plant and animal immunity against disease. The UK Soil Association carried out a systematic review of the evidence comparing trace minerals in organic and non-organic food, and found that on average, organic food contains higher levels of vitamin C and essential minerals such as calcium, magnesium, iron, and chromium [8]. An independent study found higher levels of all 21 nutrients in organic crops, particularly potatoes, cabbage, spinach and lettuce [9]. Evidence also suggests that organic crops contain up to fifty

percent fewer mycotoxins (toxins produced by fungi) and have a longer shelf life.

Organic farmers produce good food from developing a balanced living soil and using only as a last resort a handful of the hundreds of pesticides on tap to conventional farmers. Non-organic fruits can be sprayed up to 16 times with 36 different pesticides [10]. In 2003 the UK Food Standards Agency (FSA) conceded that: "...buying organic is a way to reduce the chances of your food containing these pesticides." [11]. Pesticide residues used in conventional farming such as organophosphates are linked to cancers, foetal abnormalities, chronic fatigue syndrome, and Parkinson's, [12] as well as allergies, especially in children [13], and breast cancer in women [14]. The US Government linked pesticide residues to the top three environmental cancer risks. A study in Seattle [15] found concentrations of pesticide residues 6 times higher in children eating conventionally farmed fruits and vegetables. The restriction on synthetic inputs by organic farmers prevent pesticide poisonings that cause around 20 000 deaths each year in conventional agricultural practices; and stop phosphates and nitrates leaching into drinking water.

The health benefits of organic agriculture and organic food are dealt with in more detail in Chapters 18 and 20.

Organic agriculture provides long term solutions

The FAO Report concludes that a broad scale shift to organic agriculture can produce enough food on a global per capita basis to feed the world's population over the next 50 years. Workable solutions to pressing problems such as the growth in population and consumption, oil peak, fossil fuel dependence, food transport, and agricultural sector employment are all built in holistically to the organic agriculture paradigm. Therefore, as the myth of "low yield organic agriculture" recedes [16], it is up to the agricultural researchers, officials and Governments to invest in long-term alternative agricultural systems such as green manures that can provide enough biologically fixed nitrogen to replace all the synthetic nitrogen currently used on the planet [4]. Despite scepticism at the potential of organic agriculture to feed the world [17], if conventional farmers adopted only some of its principles such as soil health and ecology, the results would already strongly benefit farmers, consumers and the environment.

- 11 -

Greening Ethiopia for Food Security

A remarkable project reversing the ecological and social damages of the Green Revolution that have locked the country in poverty

The world's largest single study of its kind now shows that composting increases yields two to three-fold and outperforms chemical fertilizers by more than 30 percent



Adi Nifas transformed by organic agriculture

Challenges

Ethiopia is a land-locked country in the 'Horn of Africa' to the northeast of the continent. Its topography is very diverse, encompassing mountains over 4 000 m above sea level, high plateaus, deep gorges cut by rivers and arid lowlands including the Dallol Depression, which is 110 m below sea level in the Afar [1].

The South Westerly Monsoon is one of the country's three moisture-bearing wind systems. Originating from the South Atlantic, it brings the greatest amount of moisture during the main rainy season (May/June-September/October). The small rains (February-April/May) originate from the Indian Ocean and feed the southern and eastern

highland areas. The third rainfall system also originates from the Indian Ocean, and feeds the southern half of the country any time between October and January, and March to May [2]. The mean annual rainfall is highest (above 2 700 mm) in the southwestern highlands, gradually decreasing to below 100 mm in the eastern lowlands of the Afar. The mean annual temperature ranges from a high of 35 C in the Afar to 10 C or lower in the highlands above 2 500 m [1]. From November to January in the highlands above 1 500 m, diurnal temperatures can range between below freezing at night, with frost, to over 25 C during the day [2].

The country faces a number of environmental

challenges resulting directly or indirectly from human activities, exacerbated by rapid population growth (population in 2007 estimated at over 77 million) and the consequent increase in the exploitation of natural resources. Most serious of all is land degradation due to the removal of self-governance from local communities of smallholder farmers, starting around the second half of the nineteenth century. This undermined the traditional systems of land management, as farmers were only able to exercise some control over their land when it was growing a crop. The most visible physical impacts are the formation of gullies eating away the soil, the recovery of vegetation prevented by free-range grazing, and the unregulated felling of trees for firewood and other purposes.

The central control of local farming communities continued under the military government (1974-1991) and did nothing to restore the farmers' confidence in controlling their own affairs and investing in their land.

These negative trends are now being reversed through the present government's emphasis on the decentralization of power down to the wereda (district), the lowest level of official government intervention, and their constituent tabias in Tigray (kebeles in the rest of the country). Each wereda is also the seat for a member of parliament in the Federal House of Representatives - the Parliament. Elected officials of the tabia run the day-to-day affairs of the local communities.

Opportunities

Despite Ethiopia's status as one of the least developed countries in the world [8], traditional agricultural production is highly diverse and is the main source of food for the population. Two of the main staple crops, the cereal teff (*Eragrostis tef*) and the root crop enset (*Ensete ventricosa*), are endemic, and many of the crops known to have their centres of origin in the fertile crescent of south-west Asia, for example durum wheat (*Triticum durum*), now have their highest genetic diversity in Ethiopia. Ethiopia is one of the eight major centres for crop diversity in the world [3].

Other important crops with high genetic diversity in Ethiopia include the cereals-barley (*Hordeum vulgare*), finger millet (*Eleusine coracana*) and sorghum (*Sorghum bicolor*); pulses-faba bean (*Vicia faba*), field pea (*Pisum sativum* including the endemic var. *abyssinicum*), chick pea (*Cicer arietinum*) and grass pea (*Lathyrus sativus*); oil crops-linseed (*Linum sativum*), niger seed (*Guizotia abyssinica*), safflower (*Carthamus tinctorius*) and sesame (*Sesamum indicum*); and root crops: anchote (*Coccinia abyssinica*), 'Oromo or Wollaita dinich' (*Plectranthus edulis*), and yams (*Dioscorea spp.*). Over 100 plant species used as crops have been identified in Ethiopia. [4]

Agriculture accounts for more than 75 percent of total exports, over 85 percent of employment; and about 45 percent of the GDP (gross domestic product). Coffee alone makes up more than 87 percent of the total agricultural exports. Hides and skins are the next most important export items as

raw, processed or manufactured goods. [5]

The Government has stated that Ethiopia's development has to be based on its capacity to produce agricultural products to ensure food security for its population, provide the raw materials for agro-industrial development and earn foreign exchange. This is set out in "Ethiopia: Building on Progress - A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10) [6].

Problems of chemical inputs

In 1995, a version of the Green Revolution, called the Sasakawa Global 2000 (SG-2000) programme [7] was introduced by the Ministry of Agriculture to boost food production through a campaign to get smallholder farmers to use chemical fertilizer along with, when possible, high yielding varieties (HYVs) and pesticides. Prior to 1995, Ethiopia had one of the lowest per capita uses of fertilizer in the world [8]. Under SG-2000, farmers were allowed to select the crops they wanted to grow with fertilizer and use the best of their own local varieties rather than buy seed of HYVs; and it is only since 2003 that more widely adapted 'improved seeds' have been promoted and taken up by smallholder farmers. But there are also efforts to promote the conservation and enhancement of farmers' varieties (often called landraces) using organic principles [9].

From 1998, the subsidy on chemical fertilizer was withdrawn and the price had more than doubled by 2007. Access to credit for purchasing fertilizer has continued to be made available to farmers up to the present. By 2001, around 5 percent of the smallholder farmers, particularly those growing maize, had become accustomed to using fertilizer. But that year, the price dropped out of the bottom of the maize market and the farm gate price in some areas fell to the equivalent of US\$ 1.50 per 100 kg [9].

In 2002, many farmers were heavily in debt and withdrew from the fertilizer schemes. Many parts of the country were also hit by a much shorter rainy season with the rains stopping early, or by drought. Consequently, yields declined, or crops failed completely and the government requested food aid for more than 14 million people, nearly a quarter of the total population [10].

Greening Ethiopia

The Environmental Policy of Ethiopia, issued in 1997, incorporated a basic principle similar to one adopted in organic agriculture [11]: "Ensure that essential ecological processes and life support systems are sustained, biological diversity is preserved and renewable natural resources are used in such a way that their regenerative and productive capabilities are maintained, and, where possible, enhanced...; where this capacity is already impaired to seek through appropriate interventions a restoration of that capability."

This enabling policy context dovetails with a unique experiment in sustainable development and ecological land management conducted with farmers in Tigray and the birth of an organic

agriculture movement in the country as a whole.

In 1995, Dr Tewolde Berhan Gebre Egziabher, founder of the Institute for Sustainable Development (ISD), was asked by some government officials to design a project that could help farmers trying to eke out an existence on the highly degraded land of the highlands. The aim was to help the farmers use an ecological approach with a minimum of external inputs to improve the productivity of their land and rehabilitate their environments. The project started in 1996 as a partnership with the Bureau of Agriculture and Rural Development (BoARD) of Tigray, and is still continuing to be run by the BoARD. The other partners in the project are Mekele University, the local communities and their local administration.

The project focuses on helping local communities restore local control and effective management of their natural resources through the development and enforcement of their own by-laws [12]. Measures used aim at:

- Improving biological and physical water and soil conservation in cropland including the control and rehabilitation of gullies
- Controlling, preferably stopping, free-range grazing to allow more grass, herbs and trees to grow
- Restoring soil fertility by making and using compost, and helping farmers avoid debt through paying for chemical fertilizer
- Incorporating grasses and fast growing legumes in areas treated for soil and water conservation.

The most successful measure has been the planting of the small multipurpose indigenous tree, *Sesbania sesban*, for animal forage and compost biomass on the bunds between fields, and in the rehabilitated gullies, along with grasses, particularly elephant grass. There has also been rapid re-establishment of indigenous plants, particularly shrubs and trees, in the gullies and on hillsides protected from grazing animals.

Project activities in four communities were established in 1996/97 and 1997/98. Since 2000, there has been a rapid scaling up of the project so that by 2006, ISD was following up project activities in 57 local communities in 12 of the 53 weredas in Tigray. Much effort has been made to include households headed by women in the project because these are generally among the poorest of the poor in their villages [12].

Since 2000, the BoARD has been promoting the land rehabilitation 'package'-compost, trench bunding for soil and water conservation with planting multipurpose trees and grasses-in over 90 communities within 25 weredas in the drier more degraded areas of the Region. By 2007, an estimated 25 percent of the farming population in Tigray were using this package, particularly making and using compost.

Results of the initial successes were published by the Institute of Science in Society in 2004 [13-15]. The Third World Network (TWN) published a fuller account in 2006 [12]; TWN had funded the project right from the beginning.

Since 2005, the Swedish Society for Nature

Conservation (SSNC) has also provided funding to ISD for promoting sustainable agriculture in Tigray, Amhara and Oromiya Regions. This included publishing a poster on making compost to support the compost manual in Tigrinya (the local language of Tigray) in 2002 [16], and distributing these to all 53 weredas of Tigray. In 2007, an Amharic version of the compost manual and poster were prepared for publication as part of the UNDP-funded Land Rehabilitation Project in the Federal Environmental Protection Authority (EPA).

In 2006, the FAO Natural Resources Department provided funding to help collect additional yield data from plots in farmers' fields during the 2006 harvesting season, and pay for the entry and statistical analysis of the data. The final database included plot yields from 974 farmers' fields and 13 crops taken over the years 2000 to 2006 inclusive [17]. The results were presented at the FAO International Conference on "Organic Agriculture and Food Security" held 2-5 May 2007 in FAO, Rome [18]

This is now the single largest study of its kind in the world comparing yields from the application of compost and chemical fertilizer in farmers' fields. The results show without any doubt that compost can replace chemical fertilizers and increase yields by more than 30 percent on average.

Compost gives the highest yields for all crops; typically double those of the 'check', and better than those from chemical fertilizer by an average of 30.1 percent



Sue Edwards and Dr Tewolde Berhan Gebre Egziabher

Organic composting superior to chemical fertilizers

An important feature of the Tigray Project is that it is largely the farmers, supported by local wereda-based experts from the BoARD, who have led the project. They choose which crops to treat with compost and which with chemical fertilizer.

The method used to collect the yield data was based on the crop sampling system developed by FAO to estimate a country's potential harvest and identify threats to local food security. Three

one-metre square plots were harvested from each field to reflect the range of conditions of the crop. The harvested crop was then threshed and the grain and straw were weighed separately. For



comparison, all yields have been converted into kg/ha in the following table.

The fields for taking the yield samples are selected with the farmers to represent the most widely grown crops. There are three treatments. 'Check' means a field that has received neither compost nor chemical fertilizer, although it may have received compost in one or more previous years. 'Compost' is for fields treated with mature compost; the rates of application range from around 5 t/ha in poorly endowed areas, such as the dry Eastern Zone of Tigray, to around 15 t/ha in the moister Southern Zone. 'Fertilizer' is for fields treated with the chemicals DAP (diammonium phosphate) and urea. The recommended rates are 100 kg/ha of DAP and 50 kg/ha of urea.

The original data were collected by community and included 13 crops, but here they have been compiled for the four most widely grown cereals and the most important pulse: barley, wheat, maize, teff, and faba bean. The results of a one-way analysis of variance (ANOVA) are given in Table 11.1, which also shows the 95 percent confidence intervals for the mean.

As can be seen, there are large differences between the means of every crop with respect to treatments. Compost gives the highest yields for all crops; typically double those of the 'check', and better than those from chemical fertilizer by an average of 30.1 percent (from 17.8 percent for faba bean to 47.4 percent for wheat).

Pairwise comparisons (not shown) of treatments for all crops are highly significant (at the 0.1 percent level or better), except for compost versus fertilizer in faba beans, where there are too few observations for treatment with fertilizer.

Farmers experience multiple benefits from composting

Farmers who have learnt how to make and use compost based on the method recommended by ISD are not interested in continuing to use chemical fertilizer, i.e. they have willingly withdrawn from the use of chemical fertilizer.

In 1998, the grain yields of all cereals without any inputs (checks), except for maize, were below 1 t/ha: 395-920 kg/ha for barley, 465-750 kg/ha for durum wheat, and 480-790 kg/ha for teff [19]. In the 7-year data set for the four widely grown cereal crops the average check yields ranged from 1116 kg/ha for barley to 1642 kg/ha for maize.

Soon, farmers began to observe and appreciate the residual effect of compost in maintaining soil fertility for two or more years. They are thus able to rotate the application of compost on their fields and do not have to make enough to apply to all their cultivated land each year.

There were many other positive impacts of composting.

Difficult weeds, such as Ethiopian wild oats *Avena vaviloviana*, have been reduced, and crops show improved resistance to pests such as teff shoot fly.

Farmers who make and use compost are able to avoid the financial risk of taking chemical fertilizer on credit, and the compost is available

Barley			95% confidence interval of mean			
Treatment	No.	Mean	(---x---)	(--x--)		
Check	165	1 116				
Compost	171	2 349				
Fertilizer	108	1 861	(---x---)			
			100	150	200	250
Wheat			95% confidence interval of mean			
Treatment	No.	Mean	(--x--)	(---x---)		
Check	219	1 228				
Compost	183	2 494				
Fertilizer	144	1 692	(---x---)			
			100	150	200	250
Maize			95% confidence interval of mean			
Treatment	No.	Mean	(---x---)	(---x---)		
Check	87	1 642				
Compost	117	3 552				
Fertilizer	69	2 736	(---x---)			
			120	240	360	480
Teff			95% confidence interval of mean			
Treatment	No.	Mean	(---x---)	(--x--)		
Check	312	1 151				
Compost	222	2 264				
Fertilizer	207	1 701	(---x---)			
			0	70	140	210
Faba Bean			95% confidence interval of mean			
Treatment	No.	Mean	(---x---)	(---x---)		
Check	60	1 379				
Compost	72	2 862				
Fertilizer	9	2 696	(---x---)			
			80	160	240	320

Table 11.1. Summary of yield data for five main crops(kg/ha)

when it is needed; chemical fertilizer is sometimes delivered too late for the farmers to use. The most visible impact of farmers not having to take fertilizer on credit is that they often invest in improving their homes and compounds, for example, replacing thatching with more water-proof corrugated iron sheets, and/or diversifying their production base by keeping beehives.

Composted fields are able to retain more moisture than untreated fields or those treated with chemical fertilizer, so that when there are dry periods, composted crops continue to grow. This was seen dramatically in 2002 when the main rains were very poor and stopped early. Crops in composted fields were still green when those in check and especially chemically fertilized fields had withered and died.

The women say that food made from grain harvested from composted fields have better flavour and provide a more satisfying and sustaining meal for their families than grain from fields treated with chemical fertilizers.

Once farmers appreciate the improved productivity of composting, they usually start to re-establish the diversity of crops, particularly cereals and pulses familiar to them before their land became highly degraded. One farmer successfully searched far and wide for 'Demehai', a variety of easily de-hulled barley used to make a snack of roasted grain, to reintroduce into his farm once he had become food secure through the use

of compost.

Farmers also become innovative in trying out new crops and crop combinations. For example, one farmer in Adi Nifas now regularly plants vegetables, particularly tomato and chilli pepper in his teff field. These do not interfere with the teff, maturing after the grain is harvested and bringing the farmer additional income. Many other farmers have now adopted this and other innovative forms of inter-cropping.

Many farmers have also started to plant fruit trees, both around their homesteads and in rehabilitated gullies. Women farmers are particularly adept at taking care of these fruit trees, such as citron (*Citrus medica*) and papaya, and they are now also starting to grow mulberry and castor (*Ricinus communis*) to raise silkworms because there is an emerging market for the silk. ISD, with financial support from SSNC, assisted the local agricultural experts of Tahtai Maichew Wereda near Axum to establish a fruit tree nursery to meet the escalating demand for fruit tree seedlings from the farmers.

In Adi Nifas, where the main gullies and hillside were treated with check dams at the start of the project, the streams from the hillside used to dry up quickly in the dry season. Now these streams hold water all year round and the resulting small river has made it possible for several farmers downstream to develop irrigated vegetable production, particularly of onions, after they have harvested their grain crops. These farmers are



Farmers' compost making workshop

able to regularly get two crops a year from their land and their land, which used to be considered as being among the worst in that area, is seen as totally rehabilitated and productive.

Organic agriculture for an end to poverty

The use of compost to restore soil fertility can go a long way towards combating poverty and ensuring food security for smallholder farmers who typically cultivate less than one hectare of land. Through indirect discussions, it appears that most of these farming families have at least sufficient food grains stored in their houses to feed their families for the whole year, and some have larger stores. One farmer who generally looked poorly dressed had his house threatened by a flood. He had to call his neighbours to help him and his family move their stored grain to a safe place because he had been able to accumulate enough to maintain his family for about three years!

In 2003, the administration of Tahtai Maichew Wereda, about 25 km west of Axum in northern Tigray, asked ISD, the federal Environmental Protection Authority and the BoARD of Tigray to help it expand the 'Sustainable Agriculture/Development Project' to all tabias in the Wereda, i.e. to over 20 000 households. The project was launched in July 2004 at a workshop involving around 200 women and men farmers, the local administration, all 50 local experts and key representatives from the Regional offices in Mekelle, the Regional capital.

An emerging challenge is the involvement of the local justice system, the 'social courts', to help uphold and enrich local by-laws to back up improvements to land and its management by the local communities.

The experience with the farmers in Tigray in producing and using compost shows that the aim for Ethiopia to have a substantial number of farmers producing organically can be realized. It also shows that the introduction of ecologically sound organic principles can have very rapid positive impacts on the productivity and well-being of smallholder farmers because they do not have to go through a conversion period of reduced yields as they go into using compost. Most farmers, particularly those in marginal areas, are not able to afford external inputs, so for them an organic production management system offers a real and affordable means to break out of poverty and delivering food security.

The organic movement is gathering momentum in Ethiopia and it is unstoppable. An Ethiopian Organic Agriculture System was approved by Parliament on 8 March 2006 [20]. The international trade in organic products is an expanding market that Ethiopia is geographically well situated to exploit, not just in the developed economies of Europe, North America and Japan, but also in the Arabian Peninsula and Near East.

Coffee was the first certified organic product exported from Ethiopia. In 1995, the world market price for coffee started to decrease dramatically and it was quickly realised that producers could improve their returns through organic production supported by fair trade. Organic fair trade coffee is

increasing its market share by about threefold each year with most of it being exported to the USA. Through these quality certificates, a minimum of 20 per cent is added on top of the local price for farmers. This has changed the livelihood of the farmers and their communities: additional schools have been built as well as health centres and several clean-water delivery points. By 2007, the Oromia Coffee Union, the first and now the largest in the country, was buying coffee from 115 cooperatives. When it started, these were the first organic certified cooperatives in Africa. This Union now sells more than 4 000 tonnes of organic coffee a year obtained from 80 000 ha of organic certified land. [21]

By 2007, there were four international organic inspection and certification bodies in Ethiopia, all with local Ethiopian experts. The certified organic products being exported are all high value products: coffee, honey, sesame, pulses, teff, pineapple, bananas, linseed, spices and herbs from farmers' fields, and incense and myrrh collected from the wild [21].

There is also an expanding awareness of the importance of producing healthy fruits and vegetables for the educated middle-class and expatriate market in Addis Ababa. For example, Genesis Farm, started in 2001, now produces high quality organically grown vegetables on an area of 40 ha. The vegetable farm has 302 permanent workers and 52 daily labourers. The farm also has a dairy herd of 110 cows and 50 000 chickens, not totally organic by European standards, but much healthier than most other animal production enterprises of a similar size in Ethiopia. There is a high demand for the products of the farm, which supplies hotels and supermarkets in Addis Ababa, as well as having its own shop on the farm. What is very interesting to note is that the prices of the products in the shop on the farm are generally the same or even somewhat cheaper than their equivalents from non-organic production units around Addis Ababa.

The future looks bright for organic Ethiopia. The rest of the world should take heart and take heed.



- 12 -

Organic Cuba without Fossil Fuels

Cuba's experience has opened our eyes to agriculture without fossil fuels, a possibility rapidly turning into a necessity as world production of petroleum has also peaked

Cuba 1989

Cuba is where agriculture without fossil fuels has been put to its greatest test, and it has passed with flying colours. The year 1989 ushered in the "Special Period" [1] a scenario that will hit some countries in the not too distant future unless they prepare for it right now.

Before 1989, Cuba was a model Green Revolution farm economy, based on huge production units of state-owned farms, and dependent on vast quantities of imported oil, chemicals and machinery to produce export crops. Under agreements with the former Soviet Union, Cuba had been an oil-driven country, and 98 percent of all its petroleum had come from the Soviet bloc. In 1988, 12-13 million tons of Soviet oil were imported and of this, Cubans re-exported two million tons. In 1989, Cuba was forced to cut the re-export in half and in 1990, oil exports were cut entirely as only 10 of 13 m tons promised by the Soviet had been received. At the end of 1991, only six of the promised 13 m tons were received, and the short fall in oil began to severely affect the nation's economy.

While oil was critical, other losses were also important, as 85 percent of all Cuba's trade was with the Soviets. Cuba exported 66 percent of all sugar and 98 percent of its citrus fruit to the Soviet bloc, and imported from them 66 percent of its food, 86 percent of all raw materials, and 80 percent of machinery and spare parts. Consequently, when support from the Soviet bloc was withdrawn, factories closed, food scarcity was widespread and an already inadequate technology base began to crumble.

The collapse of the Soviet bloc and the tightened US trade embargo exposed the vulnerability of Cuba's Green Revolution model, and it was plunged into the worst food crisis in its history [2, 3].

In early 1990, a survival economy was put in place as 100 000 tons of wheat normally obtained through barter arrangements failed to arrive and the government had to use scarce hard currency to import grain from Canada [1]. The price of food went up and bread had to be rationed. Overall, food consumption was said to decrease by 20 percent in calories and 27 percent in protein between 1989 and 1992.

To make matters worse, Cuba's efforts to



Organic intercropping in Cuba

reverse the trend of rural-urban migration over the past decades failed to stem the increasing tides of rural migrants to the cities, especially to Havana. In 1994, 16 541 migrated to Havana from all over Cuba, more than any year since 1963. By 1996,

the figure had reached 28 193, at pre-revolution level. Shortages of food and medicine and gasoline were driving people to the capital.

Policies to stop the inflow were put in place in 1997, but not before the population density in the capital reached 3 000 inhabitants per square kilometre.

Cuba was faced with a dual challenge of doubling food production with half the previous inputs, with some 74 percent of its population living in cities.

Yet by 1997, Cubans were eating almost as well as they did before 1989, with little food and agrochemicals imported. Instead, Cuba concentrated on creating a more self-reliant agriculture: a combination of higher crop prices paid to farmers, agro-ecological technology, smaller production units, and most importantly, urban agriculture. Urbanisation is a growing trend worldwide. More people now live in cities than in the countryside. By 2015 about 26 cities in the world are expected to have populations of 10 million or more. To feed cities of this size require at least 6 000 tons of food a day [1].

The Cuban response

The way Cuba responded was an inspiration to the rest of the world. It began with a nation-wide call to increase food production by restructuring agriculture. It involved converting from conventional large-scale, high input monoculture systems to smaller scale, organic and semi-organic farming systems. The focus was on using low cost and environmentally safe inputs, and relocating production closer to consumption in order to cut down on transportation costs, and urban agriculture was a key part of this effort [2-5].

A spontaneous, decentralized movement had arisen in the cities. People responded enthusiastically to government initiative. By 1994, more than 8 000 city farms were created in Havana alone. Front lawns of municipal buildings were dug up to grow vegetables. Offices and schools cultivated their own food. Many of the gardeners were retired men aged 50s and 60s, and urban women played a much larger role in agriculture than their rural counterparts.

By 1998, an estimated 541 000 tons of food were produced in Havana for local consumption. Food quality has also improved as people had access to a greater variety of fresh fruits and vegetables. Urban gardens continued to grow and some neighbourhoods were producing as much as 30 percent of their own food.

The growth of urban agriculture was largely due to the State's commitment to make unused urban and suburban land and resources available to aspiring urban farmers. The issue of land grants in the city converted hundreds of vacant lots into food producing plots, and new planning laws placed the highest land use priority on food production.

Another key to success was opening farmers markets and legalising direct sales from farmers to consumers. Deregulation of prices combined with high demand for fresh produce in the cities allowed urban farmers to make two to three times

as much as the rural professionals.

The government also encouraged gardeners through an extensive support system including extension agents and horticultural groups that offered assistance and advice. Seed houses throughout the city sold seeds, gardening tools, compost and distribute biofertilizers and other biological control agents at low costs.

New biological products and organic gardening techniques were developed and produced by Cuba's agricultural research sector, which had already begun exploring organic alternatives to chemical controls, enabling Cuba's urban farms to become completely organic. In fact, a new law prohibited the use of any pesticides for agricultural purposes anywhere within city limits.

The introduction of a diversified market-based system for food distribution has spurred increased agricultural productivity [1]. The United Nations Food and Agriculture Organization estimated that between 1994 and 1998, Cuba tripled the production of tubers and plantains, and doubled the production of vegetables, which doubled again in 1999. Potatoes increased from 188 000 tonnes in 1994 to 330 000 tonnes in 1998, while beans increased by 60 percent and citrus by 110 percent from 1994 to 1999.

Anecdotal information suggests that thousands of families have left cities and large towns to make their livelihood from the land and thousands of unemployed - including rural migrants - have found employment in urban agriculture.

Rural agro-ecology and land restructuring

Agro-ecological methods were introduced into Cuba's rural communities largely out of the necessity of coping without artificial fertilizers and pesticides; but this was also amply supported with substantial government resources, state-funded research, and fundamental policy shifts at the highest levels of government [1]. Agro-ecological farming in the countryside and organic urban agriculture were the key to stabilizing both urban and rural populations.

The agro-ecological methods introduced include locally produced biopesticides and biofertilizers substituting for the artificial chemical inputs, complex systems designed to take advantage of ecological interactions and synergisms between biotic and abiotic factors that enhance soil fertility, biological pest control, and achieving higher productivity through internal processes. Other practices involve increased recycling of nutrients and biomass within the system, addition of organic matter to improve soil quality and activate soil biology, soil and water conservation, diversification of agro-systems in time and space, integration of crops and livestock, and integration of farm components to increase biological efficiencies and preserve productive capacity.

In 1993, the Cuban government unveiled a major reorganization of agriculture, restructuring state farms as private cooperatives. The new farms, which now make up the largest sector in Cuba agriculture) were called UBPCs or Basic Units of Cooperative Production, based on a

growing perception that smaller farms would be more easily managed and better able to take on the sustainable agriculture practices.

The state retains ownership of the land, leasing it on a long-term basis, but rent-free. The cooperative, not the state, owns the production, and the members' earnings are based on their share of the cooperative's income. The UBPC also owns buildings and farm equipment, purchased from the government at discount prices with long-term, low interest loans (four percent). Most UBPCs produce sugar at given quotas, limiting any other crops that they might produce, so they have little to sell in agricultural markets, which restricts their options and income.

In addition to the UBPCs, the break up of large state farms has freed large plots of land for other use, and land has been turned over to both private farmers and agricultural cooperatives.

Small farmers working on privately owned farms and in cooperatives have made major contributions to the successful implementation of agro-ecology in the countryside.

Agricultural Production Cooperatives (CPAs) were first created 20 to 30 years ago by farmers who chose to pool their land and resources to attain greater production and marketing and economic efficiency. Although the CPAs were of minimal importance then, they began to rebound in the early 1990s. The UBPCs were modelled after them, except that farmers in the CPAs owned their land.

The Credit and Service Cooperative (CCS) is an association of small landowners joining up with other small farmers to receive credit and services from state agencies. They may also share machinery and equipment, and thus are able to take advantage of economies of scale. CCS members purchase inputs and sell products at fixed prices through state agencies, based on production plans and contracts established with the state distribution system. Any production above and beyond the contracted quantity may be sold in farmers' markets at free market prices. These small farmers have been the most productive sector in Cuban agriculture, outperforming both the CPAs and UBPCs. CCS farmers have higher incomes than members of other cooperatives.

While all farmers continue to sell a percentage of their produce to the state marketing board, farmers are now motivated to produce in excess of their agreed quota, which they can sell to agricultural markets, often at twice the contracted government price. They can triple or quadruple their income.

The urban agricultural miracle

Today, Vivero Alamar (Alamar Gardens) is an oasis amid the monotonous array of perfectly rectangular apartment blocks of Soviet-style housing in the Alamar district of eastern Havana. It is a 27-acre organic farm set in the middle of a city of two million people. Founded in 1994 on a small 9-acre parcel of land, it has become a 140-person business [6] producing a steady harvest of a wide range of fruits and vegetables: lettuces, carrots,



"Despite the tropical heat, it doesn't look like drudgery. Among organoponico employees, there is a palpable pride in their creation. The atmosphere is cooperative and congenial. There is no boss in sight, and each person seems to understand well their role and what's expected of them. The work occurs fluidly, with a quiet grace."

tomatoes, avocados, culinary and medicinal herbs, chard and cucumbers. After harvest the crops are sold directly to neighbours at a colourful farm stand. Vivero Alamar also sells a range of organic composts and mulches and a selection of patio plants. In 2005, this neighbourhood-managed worker-owned cooperative earned approximately \$180 000. After capital improvements and operating expenses, it pays each worker about \$500 a year; compared to the Cuban minimum wage of \$10 a month. Vivero Alamar is just one example of the revolution in food production that has swept Cuba in the early 1990s and continues today. From Santiago de Cuba in the east to Pinar del Rio in the west, thousands of urban gardens are blossoming. Some 300 000 Cubans are busy growing their own fruits and vegetables and selling the surplus to their neighbours.

Although urban agriculture is totally organic, the country as a whole is not. But the amount of chemical inputs has been drastically reduced. Before the crisis hit in 1989, Cuba used more than 1 million tons of synthetic fertilizers a year. Today, it uses about 90 000 tons. During the Soviet period, Cuba applied up to 35 000 tons of herbicides and pesticides a year, today, it is about 1 000 tons

Like many small poor countries, Cuba remains reliant on export agriculture to earn hard currency. It is a robust exporter of tobacco, sugar, coffee, and citrus, and is selling a significant amount of the last three as certified organic [7]. Foreign investment in such ventures is on the rise. But when it comes to sustainable agriculture, Cuba's most impressive innovation is its network of urban farms and gardens.

According to Cuba's Ministry of Agriculture, some 150 000 acres of land is being cultivated in urban and suburban settings, in thousands of community farms, ranging from modest courtyards to production sites that fill entire city blocks.

Organoponicos, as they are called, show how a combination of grassroots effort and official support can result in sweeping change, and how neighbours can come together and feed themselves. When the food crisis hit, the organoponicos were an *ad hoc* response by local communities to increase the amount of available food. But as the power of the community farming movement became obvious, the Cuban government stepped in to provide key infrastructure support and to assist with information dissemination and skills sharing.

Most organoponicos are built on land unsuitable for cultivation; they rely on raised planter beds. Once the organoponicos are laid out, the work remains labour-intensive. All planting and weeding is done by hand, as is harvesting. Soil fertility is maintained by worm composting. Farms feed their excess biomass, along with manure from nearby rural farms to worms that produce a nutrient-rich fertilizer. Crews spread about two pound of compost per square yard on the bed tops before each new planting.

Jason Marks writes [7]: "Despite the tropical heat, it doesn't look like drudgery. Among organoponico employees, there is a palpable pride in their creation. The atmosphere is cooperative and congenial. There is no boss in sight, and each person seems to understand well their role and what's expected of them. The work occurs fluidly, with a quiet grace."

Gardeners come from all walks of life: artists, doctors, teachers. Fernando Morel, president of the Cuban Association of Agronomists said: "It's amazing. When we had more resources in the 80s, oil and everything,

the system was less efficient than it is today."

The hybrid public-private partnership appears to work well. In return for providing the land, the government receives a portion of the produce, usually about one-fifth of the harvest, to use at state-run daycare centres, schools and hospitals. The workers get to keep the rest to sell at produce stands located right at the farm. It is more than fair trade.

The City of Havana now produces enough food for each resident to receive a daily serving of 280 g of fruits and vegetables a day. The UN food programme recommends 305 g.

Joe Kovach, an entomologist from Ohio State University who visited Cuba on a 2006 research delegation sums up the situation: "In 25 years of working with farmers, these are the happiest, most optimistic, and best-paid farmers I have ever met."

Long queues of shoppers form at the farm stalls, people are shopping for quality and freshness, the produce is harvested as they buy, reducing waste to a minimum.

Urban agriculture nationwide reduces the dependence of urban populations on rural produce. Apart from organoponicos, there are over 104 000 small plots, patios and popular gardens, very small parcels of land covering an area of over 3 600 ha, producing more than the organoponicos and intensive gardens combined [1]. There are also self-provisioning farms around factories, offices and business, more than 300 in Havana alone. Large quantities of vegetables, root crops, grains, and fruits are produced, as well as milk, meat, fish eggs and herbs. In addition, suburban farms are intensively cultivated with emphasis on efficient water use and maximum reduction of agrotoxins; these are very important in Havana, Santa Clara, Sancti Spiritus, Camaguey, and Santiago de Cuba. Shaded cultivation and Apartment-style production allow year-round cultivation when the sun is at its most intense. Cultivation is also done with diverse soil substrate and nutrient solutions, mini-planting beds, small containers, balconies, roofs, etc. with minimal use of soil. Production levels of vegetables have double or tripled every year since 1994, and urban gardens now produce about 60 percent of all vegetables consumed in Cuba, but only 50 percent of all vegetables consumed in Havana.

The success of urban agriculture is put down to the average Cuban citizen's commitment to the ideal of local food production [7]. There is so much for the world to learn from the Cuban experience, not least of which, agriculture without fossil fuels is not only possible but also highly productive and health promoting in more ways than one.



- 13 -

Organic Yields on Par with Conventional and Ahead During Drought Years, but Health and Environment Benefit Most

A long-term farm trial in the US comparing organic and conventional management comes out in favour of organic in all respects, with the greatest benefits for health and the environment

Myths die hard

Scientists who should know better continue to tell the world that organic agriculture invariably means lower yields, especially compared to industrial high input agriculture, even when this has long been proven false [1].

Researchers led by David Pimenthal, ecologist and agricultural scientist at Cornell University, New York, reviewed data from long-term field investigations and confirmed that organic yields are no different from conventional under normal growing conditions, but that they are far ahead during drought years [2]. The reasons are well known: organic soils have greater capacity to retain water as well as nutrients such as nitrogen.

Organic soils are also more efficient carbon sinks, and organic management saves on fossil fuel, both of which are important for mitigating global warming. But by far the greatest gains are in savings on externalised costs associated with conventional industrial farming, estimated to exceed 25 percent of the total market value of United States' agricultural output.

Long-term field trials at Rodale Institute

From 1981 through 2002, field investigations were conducted at Rodale Institute in Kutztown, Pennsylvania on 6.1 ha. Three different cropping systems: conventional, animal manure and legume-based organic, and legume-based organic. Plots (18 x 92 m) were split into three (6 x 92 m) subplots, which are large enough for farm-scale equipment to be used for operations and harvesting. The main plots were separated with a 1.5 m grass strip to minimize cross movement of soil, fertilizers, and pesticides. Each of the three cropping systems was replicated eight times.

The conventional system based on synthetic fertilizer and herbicide use represented a typical cash-grain 5-year crop rotation (corn, corn, soybeans, corn, soybeans) and reflects commercial conventional operations in the region



Rodale farm

and throughout the Midwest. According to USDA 2003 data, there are more than 40 million ha in this production system in North America. Crop residues were left on the surface of the land to conserve soil and water; but no cover crops were used during the non-growing season.

The organic animal-based cropping represented a typical livestock operation in which grain crops were grown for animal feed, not cash sale. This rotation was more complex: corn, soybeans, corn silage, wheat, and red clover-alfalfa hay, as well as a rye cover crop before corn silage and soybeans. Aged cattle manure served as the nitrogen source and applied at 5.6 tonnes per ha (dry), 2 years out of every 5 immediately before ploughing the soil for corn. Additional nitrogen was supplied by the plough-down of legume-hay crops. The total nitrogen applied per ha was about 40 kilograms per year or 198 kg per ha for any given year with a corn crop. Weed control relied on mechanical cultivation, weed-suppressing crop rotations, and

relay cropping, in which one crop acted as living mulch for another.

The organic legume-based cropping represented a cash grain operation without livestock. The rotation system included hairy vetch (winter cover crop used as green manure), corn, rye (winter cover crop), soybeans, and winter wheat. The total nitrogen added to this system per ha per year averaged 49 kg (or 140 kg with a corn crop). Both organic systems included a small grain, such as wheat, grown alone or inter-seeded with a legume. Weed control was similar in both organic systems.

Yields no different except under drought conditions

For the first five years of the experiment (1981-1985), the yields of corn grain averaged 4 222, 4 743 and 5 903 kg per ha for organic-animal, organic-legume, and conventional systems. After this transition period, corn grain yields were similar for all systems: 6 431, 6 368, and 6 553 kg per ha. Overall, soybean yields from 1981 through 2001 were 2 461, 2 235 and 2 546 kg per ha; the lower yield of organic legume system is attributed to the failure of the soybean crop in 1988, when climate conditions were too dry to support relay intercropping of barley and soybeans. If 1988 is taken out of the analysis, soybean yields are similar for all systems.



Organic soils have greater capacity to retain water as well as nutrients such as nitrogen. Organic soils are also more efficient carbon sinks, and organic management saves on fossil fuel

The 10-year period from 1988-1998 included 5 years in which the total rainfall from April to August was less than 350 mm (compared with 500 mm in average years). Average corn yields in those dry years were significantly higher (28 percent to and 34 percent) in the two organic systems: 6 938 and 7 235 kg per ha in organic-animal and organic-legume systems compared with 5 333 kg per ha in the conventional system.

During the extreme drought of 1999 (total rainfall between April and August only 224 mm), the organic animals system had significantly higher corn yields (1 511 kg per ha) than either the organic legume (421 kg per ha) or the conventional

(1 100 kg per ha). Crop yield in the organic legume was much lower in 1999 because the high biomass of the hairy vetch winter cover crop used up a large amount of the soil water. During the 1999 drought soybean yields were 1 400, 1 800 and 900 kg per ha for organic animal, organic-legume and conventional.

Other advantages of organic systems

Organic soils higher water content

Over a 12-year period, water volumes percolating through each system were 20 percent and 15 percent higher in the organic-animal and organic legume systems than in conventional. During the growing season in 1995, 1996, 1998 and 1999, soil water content was significantly higher in the soil farmed using the organic legume system than in the conventional system, accounting for the much higher soybean yields in the organic legume system in 1999.

Organic systems use less energy

About 5.2 million kilocalories of energy per ha were invested in the production of corn in the conventional system. Energy inputs for the organic animal and organic legume systems were 28 percent and 32 percent less. The energy inputs for soybean production in the organic-animal, organic legume and conventional systems were similar at 2.3 m kcal, 2.3 m kcal, and 2.1 m kcal respectively.

Income unchanged

Economic comparison of the organic corn-soybean rotation with conventional corn-soybean systems from 1991-2000 showed that even without price premiums for the organic rotation, the annual net returns for both were similar: \$184 per ha for conventional, \$176 per ha for organic legume (Table 13.1).

More carbon sequestered in soil

Soil carbon at start (1981) was not different between the three systems. In 2002, however, soil carbon levels in the organic animal and organic legume systems were 2.5 percent and 2.4 percent versus 2.0 percent in the conventional. The annual net aboveground carbon input (based on plant biomass and manure) was the same in organic legume system and conventional system (~9 000 kg per ha), but about 10 000 kg per ha in organic animal system. However, the two organic systems sequester more of that carbon in the soil, resulting in an annual soil carbon increase of 981 and 574 kg in the organic animal and organic legume systems, compared with only 293 kg per ha in the conventional systems (calculated on the basis of about 4 million kg per ha of soil in the top 30 cm.). Total soil carbon increase after 22 years was: 27.9

	Organic Legumes	Conventional
Seed	\$103	\$ 73
Fertilizers & Lime	\$ 18	\$ 79
Pesticides	\$ 0	\$ 76
Machinery	\$154	\$117
Hired Labour	\$ 6	\$ 9
Total	\$281	\$354
Revenue	\$457	\$538
Net Income	\$176	\$184

Table 13.1. Annual costs per ha

percent, 15.1 percent and 8.6 percent in organic animal, organic legume and conventional systems.

More nitrogen retained in the soil and less leaching

Soil nitrogen levels started at 0.31 percent in 1981. By 2002, the conventional system remained unchanged, while organic animal had increased to 0.35 percent and organic legume system to 0.33 percent. Using ^{15}N to measure retention of N in soil it was estimated that 47 percent, 38 percent and 17 percent respectively of the nitrogen from organic animal, organic legume and conventional was retained in the soil each year after application. This matched the decreased amount leached from the organic soils.

No herbicides leached into groundwater

Four herbicides were applied in the conventional system: atrazine (to corn), pendimethalin (corn), metolachlor (corn and soybeans) and metribuzin (soybeans). From 2001 to 2003, only atrazine and metolachlor were detected in water leachates collected from conventional systems at levels in excess of 3 parts per billion, exceeding maximum contaminant level set by US EPA for atrazine (no level has been set for metolachlor).

Increased soil biodiversity

Soils farmed with the two organic systems had greater populations of spores of the beneficial Arbuscular mycorrhizal fungi, shown to enhance disease resistance, improve water relations and increase soil aggregation.

Large amounts of biomass (soil organic matter) are expected to significantly increase soil biodiversity. Microarthropods and earthworms were reported to be twice as abundant in organic versus conventional agricultural systems in Denmark. Earthworms and insects create holes in the soil that increase the percolation of water into the soil and decrease runoff.

Labour requirements

Each system was allowed 250 "free" family labour per month; while the cost of hired labour was \$13 per hour. With organic farming system, the farmer was busy throughout the summer with the wheat crop, hairy vetch cover crop, and mechanical weed control but worked less than 250 hours per month. In contrast, the conventional farmer had large labour requirements in the spring and fall, planting and harvesting, but little in the summer months.

Increase in labour input may range from 7 percent to a high of 75 percent in organic compared to conventional systems. But in situations where human labour is not in short supply, this too can be an advantage of organic agriculture in creating employment.

The externalised costs of conventional agriculture not taken into account

By far the biggest gains from organic agriculture arise from the savings on the damages to public health and the environment due to the use of agrochemicals in conventional agriculture.

The National Organic Standards Program in

the United States prohibits the use of synthetic chemicals, GMOs and sewage sludge in organically certified production.

Pimental pointed out [2] that the estimated environmental and healthcare costs of pesticide use at recommended levels in the US is about 12 billion every year. According to the National Research Council [3], the cost of excessive fertilizer use is \$2.5 billion per year, while the estimated annual costs of public and environmental health losses related to soil erosion greater than \$45 billion [4].

The total externalised cost of conventional agriculture per year is \$59.5 billion. This represents 27.4 percent of the entire agricultural output (\$217.2 billion in 2002 [5]).

The biggest gains from organic agriculture arise from the savings on the damages to public health and the environment due to the use of agrochemicals in conventional agriculture. The total is \$59.6 billion, or 27.4 percent of the entire agricultural output of the US in 2002

- 14 -

Organic Cotton Beats Bt Cotton in India

Organic cotton from indigenous varieties incomparably superior to genetically modified Bt cotton in all respects



Bt (left) and non-Bt cotton in Warangal, India

Organic cotton is more environmentally friendly, better for the health of the community and for the local economy than GM cotton, according to a study by the Centre for Sustainable Agriculture in Andhra Pradesh [1]. The GM Bt cotton was compared with cotton grown without pesticide, i.e., under non-pesticide management (NPM).

The study looked at the incidence of various pests and diseases as well as the beneficial organisms in the Bt and NPM cotton fields. It also looked at the economics of pest management for both systems.

The study, designed and supervised by

entomologist Dr S.M.A. Ali, extension scientist G.V. Ramanjaneyulu, and development activist Ms Kavitha Kuruganti, involved end-of-season interviews with cotton growing farmers in Warangal and Medak districts.

A total of 121 NPM cotton farmers farming on 193 acres and using no synthetic pesticide were compared with 117 Bt cotton farmers using proprietary pesticides and farming 151 acres. The Bt cotton varieties grown were Mech 12 (88 farmers), Mech 184 (1 farmer), and RCH 2 (31 farmers); a few farmers grew more than one of these varieties on different plots, hence the sum of

farmers is more than 117).

These Bt varieties all carried Monsanto's cry1Ac gene and display low genetic diversity; providing early pest resistance [2]. NPM cotton farmers grew many varieties including Brahma, Maruthi, Dasera, Gemini, Sumo, Tulasi, Bhagya, Durga, Kranthi.

Ten villages in two districts took part in the Bt cotton survey, and 12 villages from two districts took part in the NPM survey.

Bt cotton more prone to pests and diseases

Overall, the NPM farmers reported a lower incidence of medium to high infestations and higher incidence of low or no infestations for four traditional cotton pests.

Surprisingly, 32.5 percent of Bt cotton farmers reported a high incidence of American bollworm, an important pest that the Bt cotton is designed to control; while only 4.1 percent of NPM farmers reported a high incidence of this pest. This single statistic questions the value of the Bt approach to pest control. It also corroborates the high incidence of bollworm reported by farmers growing Bt cotton in AP [3]. In contrast, the efficacy of natural predators and/or natural pesticides to control American bollworm in particular, and the other bollworms in general, is remarkable (see Table 14.1).

A majority of NPM farmers reported low incidence of spotted bollworm (76.9 percent against 65.8 percent of Bt growers), American bollworm (76.1 percent against 17.1 percent of Bt growers), and Tobacco Caterpillar (76.8 percent against 64.1 percent of Bt growers). Six NPM farmers reported an absence of spotted bollworm compared to two Bt farmers.

A majority of NPM farmers reported a medium incidence of pink bollworm, as did their Bt



Level of incidence	Spotted Bollworm		American Bollworm		Tobacco Caterpillar		Pink Bollworm	
	Bt	NPM	Bt	NPM	Bt	NPM	Bt	NPM
High	15 (12.8)	4 (3.3)	38 (32.5)	5 (4.1)	8 (6.8)	2 (1.7)	20 (17.1)	25 (20.7)
Medium	23 (19.7)	18 (14.9)	59 (15.4)	24 (19.8)	34 (29.1)	22 (18.2)	67 (57.3)	57 (47.1)
Low	77 (65.8)	93 (76.9)	20 (17.1)	92 (76.1)	75 (64.1)	93 (76.8)	29 (24.8)	38 (31.4)
Nil	2 (1.7)	6 (4.9)	0 (0)	0 (0)	0 (0)	4 (3.3)	1 (0.8)	1 (0.8)

Table 14.1. Incidence of Bollworm complex on Bt and NPM cotton

Level of incidence	Jassids		Thrips		Whitefly		Aphids		Mites	
	Bt	NPM	Bt	NPM	Bt	NPM	Bt	NPM	Bt	NPM
High	52 (44.5)	7 (5.8)	1 (0.8)	0 (0)	39 (33.4)	2 (1.6)	35 (29.9)	1 (0.8)	21 (17.9)	3 (2.5)
Medium	42 (35.9)	20 (16.5)	21 (17.9)	8 (6.6)	35 (29.9)	15 (12.4)	43 (36.8)	20 (16.6)	45 (38.6)	10 (8.3)
Low	22 (18.8)	94 (77.7)	92 (78.7)	107 (91.5)	41 (35.0)	90 (74.4)	39 (33.3)	95 (78.5)	50 (42.7)	101 (83.5)
Nil	1 (0.8)	0 (0)	3 (2.6)	5 (4.9)	2 (1.7)	14 (11.6)	0 (0)	5 (4.1)	1 (0.8)	7 (5.7)

Figure in parentheses is percentage of respondents

Table 14.2. Incidence of sucking pests on Bt and NPM cotton.

counterparts (47.1 percent against 57.3 percent), but greater numbers of NPM farmers also reported a low incidence of this pest compared to Bt farmers (31.4 percent against 24.8 percent).

In the case of sucking pests, the majority of NPM farmers also reported a low incidence, with several reporting no infestation of whitefly, aphids and mites. Again, natural predators and pesticides can be seen to be more effective at controlling sucking pests than Bt cotton. Many Bt farmers reported a high incidence of jassids, whitefly and aphids, but Bt toxins are known to be ineffective against sucking pests [4], therefore, farmers necessarily use additional pesticides specific to these pests (see Table 14.2).

Wilt, a common disease of cotton was reported absent by only 17 of the Bt cotton farmers during the season (14.5 percent), while 50 NPM farmers reported no wilt problems (41.3 percent). The degree of wilt ranged from 30 - 70 percent for Bt cotton, but was only 10 - 15 percent for the NPM cotton varieties. While wilt causes a decrease in cotton yield, the traditional cotton varieties have far greater genetic diversity than the Bt cotton, giving greater security against losses from this disease.

Beneficial insects prevail on NPM cotton

These findings reflect the fears of many



Placard says beware of Bt cotton



Bt cotton crop pest damage and disease

environmentalists that the Bt cotton endotoxin destroys many beneficial insects [5], and that has a knock-on effect on the birds and small mammals that are the natural predators of these insects. Table 14.3 shows 85 (70.2 percent) of NPM farmers finding a high incidence of beneficial insects on their crop, with 97 (82.9 percent) of Bt cotton respondents finding only a low incidence and 13 (11.2 percent) Bt farmers found no beneficial insects at all on their crop.

The main strategy of NPM farmers' pest control on their crops is through beneficial insects that are predators of cotton pests; they also use natural organic pesticides. In contrast, Bt farmers report a low incidence of pest predators due to the toxicity of the Bt varieties and associated pesticides, necessitating a vicious cycle of synthetic pesticides to keep pests down.

Economics of pest management shows Bt cotton extortionate

Purchase of Bt cotton seed, genetically modified with the cry1Ac gene from soil bacterium, *Bacillus thuringiensis*, includes a technology fee, and costs farmers Rs 1600 per acre, compared to NPM farmers who buy their seed at Rs 450 per acre.

This makes Bt cottonseed cost 355 percent the traditional varieties [1].

Incidence level of beneficial insects	Fields	
	Bt Cotton	NPM Cotton
High	0 (0)	85 (70.2)
Medium	7 (5.9)	26 (21.5)
Low	97 (82.9)	8 (6.6)
Nil	13 (11.2)	2 (1.7)

Figure in parentheses is percentage of respondents

Table 14.3. Incidence of beneficial insects on Bt and NPM cotton.



In addition, pest management costs were greater for Bt farmers who had to use pesticides such as Monocrotophos, Confidor, Tracer, Avaunt, Endosulfan, acephate, demethoate, imidacloprid, quinalphos, chlorpyrifos, cypermethrin etc to manage a variety of pests including bollworms for which Bt toxin is supposed to be specific.

On average, Bt crops were sprayed 3.5 times, with two farmers reporting that they did not spray at all, and others spraying as many as seven times. The NPM farmers used no synthetic pesticides, but used natural pesticides such as Neem seed kernel extract, trichoderma and panchakavya.

Bt cotton pest management cost on average Rs 2 632 per acre, whereas NPM cotton pest management cost on average Rs 382 per acre, making pesticide costs 690 percent for the Bt cotton farmers.

Yields and incomes were not included in this study as cotton picking was still going on at the time of data collection, but Bt cotton yield and quality has been well documented as lower than traditional varieties [6], in spite of claims to the contrary. Yet the study clearly proves that restoring the ecological balance in the cotton fields, by removing both the GM endotoxins and the synthetic chemicals, will bring both short and long term benefits to farmers and the environment.

The study punctured a number of myths in the current pest management paradigm:

1. Pests can be controlled only with pesticides, whereas prevention is better than cure
2. All insects in the fields are pests, whereas they include natural predators that kill pests
3. No relationship exists between monoculture and pest incidence, whereas a reduced genetic base

over large areas results in unobstructed proliferation of the pest especially as in India where non-Bt cotton refuges are not used [2]

4. Chemical fertilizers and pest incidence are unrelated; whereas chemical fertilizers increase plant vulnerability to the pest due to increased 'succulence'
5. Pest resistance is a genotypic rather than an environmental issue, whereas environmental management of pests will give farmers more control over their crops than the use of patented seed derived from manipulating genes
6. Pest resistance management is about using newer and newer generation pesticides, whereas NPM systems cut costs to farmers and the environment leading to greater independence of farmers and a healthier, more biodiverse environment
7. Prevention of pest/disease means spraying even when the pest is absent, whereas pest management is not about schedules or routine but the needs of the actual situation
8. Benefits of synthetic pesticides outweigh the risks, whereas suicides [7] in the Indian cotton belts show that the economics of pesticide use do not add up, even before other adverse effects are taken into account, such as increased crop water consumption [8].

The story of Punukula: it's not rocket science

Punukula, a small village in Andhra Pradesh, with a population of about 860, has rediscovered the art and science of sustainable cotton cultivation by using NPM systems. But this small revolution in India's cotton belt has been ignored by agricultural scientists, perhaps because it is an appropriate technology that does not lend itself to exploitation by outsiders, and because it does not have the 'glamour' of 'cutting edge technology'.

Nevertheless, it so impressed the AP agriculture minister, who witnessed the transformation for himself, that it has been replicated in 400 surrounding villages [7].

A few farmers from a local non-governmental organization began in 1999 (before the arrival of GM cotton in India), to experiment with NPM practices on their cotton crop, and persuaded 20 local farmers to try it.

The environment, previously contaminated by a vicious cycle of pesticide application began to improve, and the pest burden reduced. By 2004, the environmental and economic impact was such that the entire village was using NPM that had restored natural pest control systems, and they therefore had no reason to adopt GM cotton when it became available.

In the early 1960s, only six or seven major pests worried the cotton farmer, but costly inputs prescribed by agribusiness and agricultural research has created a spiral of pollution, debt and death that has also resulted in the farmer fighting 70 major pests on cotton today. Although average yields for farmers in Punukula are greater than for Bt cotton farmers, most mainstream agricultural scientists, and politicians prefer to

support GM technology and agribusiness.

If Punukula had adopted GM Bt cotton, the village would have paid Rs 600 000 in additional seed price for the 500 acres under cultivation (Rs1 200/acre technology fee), before addressing the extra cost of pesticide application. The farmers would have remained caught in the spiral of debt as victims of the 'cutting edge technology' that draws millions of rupees from the small rural economy into the pockets of powerful multi-nationals every year.

And indeed, that was what happened in the rest of Andhra Pradesh.

The conclusive finding is that Bt cotton is more prone to pests and diseases and that beneficial insects are more prevalent on NPM cotton.

How AP became the 'Pesticide Capital of the World'

In the fertile regions of Andhra Pradesh (AP), 'white gold' monocultures of the high yielding hybrids of 'Green Revolution' cotton had turned the state into the pesticide capital of the world even before the advent of Bt cotton.

Many of the cotton varieties once grown with a diversity of food crops were swept aside and lost during the 1970s and 80s when the high yielding varieties (HYVs) of the Green Revolution arrived, and the irrigation infrastructure developed. These HYVs are expensive hybrids that have to be purchased every year from seed dealers and nurtured with expensive inputs of fertiliser and pesticide, being far more vulnerable to pests and the vagaries of the weather than the hardy local varieties that they had replaced.

Farmers initially saw the system of industrial production as timesaving and requiring far less knowledge of soils and pests; however it soon proved to be a relentless treadmill. It degraded the soil, depleted scarce water resources and proliferated cotton pests beyond the farmers' worst nightmares, as both yield and profit progressively diminished. Pest resistance and distortion of natural predator communities necessitated galloping applications of the most toxic chemicals. Some 55 percent of all pesticides used globally are on cotton, more in AP than anywhere else in the world. GM cotton hybrids, far from being the solution to proliferating pesticide use, will actually accelerate this trend.

Indeed, many poor farmers and labourers can be seen with their pesticide back-packs moving backward and forwards along the rows of cotton through a haze of spray, with no protective mask or clothing. These farmers are very aware of the problems of pesticides, and many thousands of them are killed either passively through poisoning or actively through suicide when their crops fail (see Chapter 23).

The Green Revolution turning back full circle

The revolution is turning full circle as more and more farmers began opting for low input organic methods that are healthier and economically far more rewarding, and recovering their indigenous

crop varieties.

Non-governmental organisations are working in many villages to promote and train small and marginal farmers in NPM of cotton leading to organic production in the third year of uptake, as I discovered in my visit to India towards the end of 2005.

Mr MD Amzad Ali of Sarvodaya Youth Organisation, Mr G Raja Shekar of the Centre for Sustainable Agriculture, Hyderabad, and Mr Y Kambaram of Modern Architects of Rural India introduced me to farmers who have been practising NPM cotton production and had moved on to organic cotton production after two years. By making and applying their own natural fertiliser they were able to access a high quality premium of 200 rupees per quintal (1 quintal = 100 kg) at a price of around Rs1900/q.

The farmers and NGOs organised four local cooperatives of between 100 and 500 farmers that soon became self-sufficient and able to pay their way in the local market, adding substantially to the local economy. Farmers who complete the five year programme - of two NPM years followed by three organic years - become trainers and role models for new entrants.

Tookya Niak knew farmers who planted GM Bt cotton that failed and committed suicide, and decided to try the NPM method himself. In his second year, he stressed that the low investment required will almost certainly lead to a profit, and that farming had become virtually free from stress as his debt was minimal.

He was confident that his variety was hardy and dependable and that he could remove most pests during the early immobile stages in their life cycle through his skill in selecting an effective deterrent. He also no longer worried about the health of his young family, and expected that his yield would rise as his soil improved and insect communities reached a natural balance. He was still expecting about seven quintals per acre on his poor red soil.

Indeed Niak had become such a beacon in his community that the village has been renamed after him and the NPM credo written on the walls in the village square to counter the pro Bt cotton posters found everywhere. Niak's positive appraisal of the NPM method and its advantages were confirmed by all the other farmers we interviewed.

Recreating the natural balance of predators and pests

The skill of managing pests without recourse to synthetic pesticide requires knowledge of life cycle and behaviour, vigilance, an armoury of pest specific deterrents, and a healthy community of natural predators of pests. To control pests such as the spotted bollworm, American bollworm, tobacco caterpillar, pink bollworm, aphids, jassids, thrips, white fly and mites, each of which is capable of causing between 30 and 50 percent damage to a crop, natural predators are the most effective year after year.

For example, trichogramma, a tiny parasitic wasp, lays its eggs in the eggs of the American bollworm; bracon, another parasitic wasp, lays its

eggs in bollworm larvae. Hoverfly larvae feed on aphids; pirate bugs feed on bollworm larvae, and big-eyed bugs feed on bollworm larvae and white fly. Chrysopa, a lacewing, feeds on bollworm caterpillars and sucking pests; ladybird beetles and larvae feed on aphids and deter Spodoptera. Ground beetles and dragonflies feed generally on crop pests, and robber flies, predatory wasps and red tree ants steal bollworm larvae for the young in their nests. Preying mantis and spiders are also predators of cotton pests; as are many insectivorous birds for which perches are erected throughout the crop.

Mechanical and chemical aids to pest reduction include pheromone, light, kerosene, water, and yellow and white coated grease traps that are laid within the crop as a particular pest proliferates. Castor plants are grown that capture tobacco caterpillar eggs and marigolds that capture American bollworm allow these pests to be 'nipped in the bud'. Specific pests may be sprayed with a mixture of fermented cattle dung and urine that also add micronutrients that help wilt and other

diseases. Neem seed kernel extract, chilli/ ginger/ garlic extract, a tobacco decoction and jaggari solution, made from the residue of sugar cane, are used to deter a variety of destructive insects. Unlike the use of pesticides, none of these biological/organic control methods will lead to pest resistance or harm the environment; instead, they serve to restore the ecological balance and to increase the farmers' health, profit, knowledge and independence.

Organic farmers regain full independence

The third year of the NPM programme is the organic stage of cotton production, and is run by Oxfam. Oxfam has accessed a traditional Tamil Nadu non-hybrid variety called surabhi from the Central Institute of Cotton Research in Coimbatore. This variety has an excellent staple length and is therefore popular with buyers. It also has resistance to both pests and diseases such as bacterial leaf blight, and grows well in conditions similar to those in AP.

Moreover, the surabhi seed costs Rs130 per acre, as opposed to Rs450 per acre for hybrid cotton and Rs1600+ per acre for GM Bt cotton. It will give a standard yield of 3 to 4 quintals per acre in poor conditions, though in good conditions last year, it yielded 8 quintals per acre. More importantly, it yields viable seed that puts seed control back in the farmers' hands, allowing them to retain and propagate the line; an unusual benefit in this age of hybrids.

So with freely available local fertilisers such as tank silt, vermicompost and green manure, and cheap natural pest control inputs, a profit from the crop is almost inevitable, giving peace of mind to the farmer, who can repay any debt to the cooperative for lending to new members.

As mentioned earlier, scientific research backs up the farmers' experience [1]. The conclusive finding is that Bt cotton is more prone to pests and diseases and that beneficial insects are more

prevalent on NPM cotton.

The greatest triumph for organic cotton happened when the AP Minister of Agriculture Mr Raghuvendra Reddy got the failed Monsanto cotton hybrids - Mech-12 Bt, Mech-162 Bt and Mech-184 Bt - banned in the state in May 2005, and is now supporting the expansion of the NPM programme since witnessing its success in the village of Punukula.

Madhavi from Oxfam said that the multinational companies have corrupted seed dealers who gain a much larger profit on each drum of Bt seed sold than non-Bt seed, and although the Bt crop looks destined to fail again that year, most illiterate farmers, through wishful thinking, have believed the hype of the profiteers. They remain caught in a cycle of debt, pesticide and despair.

But the transition to organic cotton has been very successful where implemented and Oxfam is seeking to give more farmers this sustainable option and will expand its programme to other crops, including rice, in the near future. This is the opportunity that small farmers need to avoid falling into the Bt cotton trap, and return to autonomy and financial independence.

Farmers stop spraying chemical pesticides, yields go up

Farmers in India are not alone. In two years, 2 000 poor rice farmers in Bangladesh reduced insecticide use by 99 percent.

Gary John, senior scientist at the International Rice Research Institute in Manila, said: "To my surprise when people stopped spraying, yields didn't drop, and this was across 600 fields in two districts over four seasons. I'm convinced that the vast majority of insecticides that rice farmers use are a complete waste of time and money." In the Philippines, similarly, a decline in insecticide use has been accompanied by an increase in productivity leading to great savings for farmers [9].

This came as a revelation only after land and water have been poisoned, the environment degraded, and, according to WHO figures, 20 000 people have died from pesticide poisoning worldwide annually. And because science has viewed all things traditional as backward and substandard the collective wisdom of generations of farmers has been largely lost; and at the same time agricultural scientists are still promoting useless and harmful technologies like genetic modification [10].

But while ordinary farmers are getting wise to GM propaganda and hard sell around the world, an Indian government study has found serious faults with its GM Bt cotton under commercial production. The government has been sitting on this study for two years. It describes a multitude of problems already experienced by farmers but previously denied by its own scientists and politicians [11].

Agronomic Benefits

- 15 -

Organic Production Works Soon after Conversion

A study shows organic production outperforms conventional in crop yield, soil fertility, pest reduction and economic return, soon after conversion from conventional

Experiment following transition to organic

Increasing public demand for organic products attracts premiums for the certified organic farmer, and hard-pressed conventional farmers are going organic. In the US, a 20 percent annual growth rate has boosted sales of organic produce to \$8 billion in 2001; and incentives to farmers to go organic were offered in the 2002 Farm Bill, including cost sharing, and direct payments for conservation practices, such as longer crop rotations [1].

Kathleen Delate of Iowa State University and Cynthia A. Cambardella of the US Department of Agriculture assessed the agro-ecosystem performance of farms during the three-year transition it takes to switch from conventional to certified organic grain production [2]. Strategies for lowering the risk of yield loss during this period have been researched, as productivity generally decreased initially when fertilizer and pesticide applications are withheld. But productivity usually improves in successive years under organic management to equal that in conventional farms. The study found that organic grain crops can be successfully produced in the third year of transition and that additional economic benefits can be derived from expanded crop rotation.

The experiment, lasting four years (three years transition and first year of organic certification), tested the hypothesis that organic systems relying on locally derived inputs are capable of providing stable yields while maintaining soil quality and plant protection compared with conventional systems with less diverse crop rotations and greater levels of external, fossil-fuel based inputs. The experimental design involved a completely randomised four replications of four different cropping system treatments.

The researchers looked at the effects of organic farming practices, including crop rotation, cover cropping, compost application, and non-chemical weed control on soil fertility, crop yield, and grain quality compared with the conventional system. They assessed pests and plant response under various crop rotations, and determined which certified organic drop rotations reduced the risks



Kathleen Delate

from low yield and improved soil properties and economic returns.

Organic performed as well or better

During the four-year period, corn yield in the organic system averaged 91.8 percent of conventional corn yield and soybean yield in the organic system averaged 99.6 percent of conventional soybean yield. By year three, there was no significant difference between organic and conventional yields; and both organic corn and soybeans exceeded conventional yields in the fourth year (the first year after certification).

In the initial year of transition, an economic advantage could be gained by planting legume hay crops or crops with a low nitrogen demand in fields with low productivity, to increase fertility for the following corn crop. In the second year, yield

differences were mitigated by rotation and compost application, providing sufficient nutrients for the organic grain crop. The yields in year three were similar, but the importance of a soil-building cover crop, or legume grass mixture such as the oat-alfalfa mixture used in this study was apparent in the fourth year when organic corn and soybean yields out-performed the conventional crops.

In the initial year of transition, an economic advantage could be gained by planting legume hay crops or crops with a low nitrogen demand in fields with low productivity, in the second year, yield differences were mitigated by rotation and compost application, providing sufficient nutrients for the organic grain crop. The yields in year three were similar, in the fourth year organic corn and soybean yields exceeded conventional

Other benefits

The researchers thought that timely weed management and sufficient levels of nitrogen, phosphate and potassium in the organic system contributed to good yields during transition. Yield increases were obtained after three years because of available nitrogen due to organic amendments, such as composted pig manure and the inclusion of forage legumes and other green manures in extended crop rotations.

Soil fertility depends on the constant renewal of biologically available nitrogen to replenish the organic nitrogen pools for plants to absorb. Total

nitrogen levels showed an increase of 457 kg per hectare in organic soil over four years, or an average increase of 114 kg N per ha per annum, sufficient to maintain organic nitrogen pools in this system. Total organic calcium increased 9 percent in organic soil over the transition period, with no significant increase in non-organic soil.

The researchers found weed pressure in the organic corn and soybean systems manageable, and that it was less in organic soybean than in corn plots where rye was not used as a cover crop. In the soybean-rye rotation, weed densities were equivalent to conventional systems in the first two years, and significantly less in the third year. Grass and broadleaf weed populations varied between the organic and conventional systems each year, but the impact on yield was negligible. Corn borer and bean leaf beetle populations were similar between systems, again with no effect on yield.

Economic returns in the organic corn-soybean-oats/alfalfa and the organic corn-soybean-oats/alfalfa-alfalfa rotations were significantly greater than those in the conventional corn-soybean rotation, as organic soybean commands premium prices in the organic rotation due to increased demand.

A previous study had found enhanced soil fertility and higher biodiversity were correlated with less dependence on inputs in the organic systems, reducing fertilizer and energy inputs by 44 percent and pesticide by 97 percent.

Kathleen Delate gives information to 200 in August 2006



- 16 -

System of Rice Intensification Increases Yields

The first reality check of a low-input rice-growing system turned out very favourable, and more successes documented since

First reality check

System of Rice Intensification, SRI, is a rice cultivation and management regime invented in Madagascar in the 1980s that gives higher yields with greatly reduced water input (see Chapter 27). The clearest sign that SRI works, if not miracles, then certainly well enough, is the number of participants drawn to the first in-depth international assessment of it.

Nearly a hundred people from 18 countries were listed as participants in the 192-page proceedings [1] of the 4-day conference, which took place in Sanya, China, in April 2002. More than three-quarters were scientists, with policy-makers, representatives of non-government organisations, international organisations, private companies and farmers making up the rest. Participants from the host country China made up more than half of the total, and all were scientists from prestigious rice research institutes, agriculture academies or universities.

The conference was convened, not to assess

whether SRI works - for that was the experience of almost everyone who presented papers at the conference - but to assess across nations, "the opportunities and limitations" of a practice that "can give yields about twice the present world average without reliance on new varieties or agrochemicals."

The conference did bring together a substantial body of evidence from around the world that SRI can increase yield in a variety of soils, climatic conditions, with various local adaptations, and using both indigenous and commercial 'high yielding' rice varieties.

SRI has been "practice-led" thus far, but participants at the conference felt it was time for scientists to catch up and research the knowledge-base, so that a healthy dialectical relationship between practice and knowledge can be achieved to help advance this important project of delivering food security and health to more than half the world's population.

Since then, more successes have been



Profusion of rice panicles with SRI

reported, leaving the scientific establishment even further behind (see Chapters 28)

The province of Fianarantsoa, situated in the south-central highlands of Madagascar, now lays claim to the highest yielding rice-fields in the world since the introduction of SRI in the 1990s.

The highlands are subtropical, with annual rainfall averaging 1 375 mm. The rainy season occurs during the hot months in the year, where the average temperature rises above 20 C. The Fianarantsoa region is often affected by cyclones during the rainy season.

Fianarantsoa attained rice yields of more than 8 t/ha in the first year of applying SRI methods, up from the 2 t/ha national average. SRI in this region is increasingly linked with the use of compost in rotational cropping with potatoes, beans or other vegetables in the off-season. In the second and succeeding years, the residual and cumulative effects of soil organic matter from composting increased yields still further, to 16 t/ha. By the sixth year, yields as high as 20 t/ha were measured on farmers' fields in Tsaramandroso, Talatamaty and Soatanana.

Bruno Andrianaivo, senior agronomist of FOFIFA (National Centre for Applied Research on Rural Development in Madagascar) emphasized that such high yields cannot be achieved immediately, but requires the cumulative effects of 6 years under SRI.

However, simply on the conservative figure of 8 t/ha yield from SRI practice Andrianaivo estimated a net return to the farmer of 5 million Fmg (about US\$770), compared with around 250 000 Fmg (less than US\$40) for conventional practice.

The total savings with SRI method in seed, fertilizer and water amounted to 1 565 Yuan/ha; add to that a 15 percent increase in yield and the farmer gets a total additional profit of 3 000 Yuan/ha (US\$360)

Acceptance in China

Professor Yuan Longping of China National Hybrid Rice Research and Development Centre played a key role in creating high-yielding super-hybrids throughout the late 1990s and early 2000s by conventional breeding methods. His Centre had already broken all records in boosting rice-hybrid yields when he first heard about SRI from a paper written by Norman Uphoff of Cornell International Institute for Food, Agriculture and Development.

Yuan conducted the first trial of SRI in his Centre's station in Sanya from winter 2000 to spring 2001. Only three varieties yielded above 10 t/ha, and SRI gave an average increase of around 10 percent over the conventional practice. The following year, tests were conducted in the summer at the Centre's station in Changsha. Two varieties yielded 12 t/ha, and one 12.9 t/ha, a record for the Centre so far. This encouraged more Chinese scientists to conduct SRI research. Of the 8 locations in which his Centre was involved, 5 locations got good results, with yields over 12 t/ha.

Since then, trials by a private sector company, the Meishan Seed Company in Sichuan Province, using a modified SRI method, achieved yields of

15.67 t/ha and 16 t/ha in two different plots, both new records in Sichuan Province (yield in the conventional field was 11.8 t/ha).

Yuan's preliminary evaluation of SRI was enthusiastic: "SRI is a promising way to increase rice yield and to realize the yield potential of any variety...whether high-yielding variety (HYV) or local variety." He confirmed that the method can promote more vigorous growth of rice plants, especially tillers and roots, and noted in addition, less insect and disease problems during the vegetative growth stage, and that there are definite varietal differences in response to SRI practices: those with strong tillering ability and 'good plant type' are more favourable for SRI cultivation. "SRI gives higher output with less input, but requires very laborious manual work which makes it more suitable for small farms in developing countries" he said. Moreover, SRI should be modified and adapted to suit local conditions, and as experience teaches.

For China, he recommended a long list of modifications, including using tray nurseries to raise the young seedlings instead of flooded seedbeds, so as to reduce the trauma of transplanting; and controlling tiller-formation, for although increased tillering gives many more rice-forming panicles, the percentage of productive tillers falls off with the number of tillers, so there is an optimum maximum number.

Yuan definitely thinks there is scope for combining genetic improvement with SRI methods. For example, breeding plants with a strong ability to form tillers would be appropriate for improving the response to SRI.

Detailed analyses of the trials were presented in several multi-author research papers. For example, the economic benefits of applying SRI methods were estimated for the hybrid rice Liangyoupei 9, which came both from savings and increased yield. The amount of hybrid seed needed in SRI methods was only 3 - 4.5 kg, which represented a seed saving of 8.3 - 10.5 kg and nursery saving of 90 percent, thereby reducing the cost by 215 Yuan/ha. As only compost was applied, the saving on the 10-12 t/ha fertilizer that would have been used was 1 200 Yuan/ha. The saving on water, some 3 000 tonnes, was about 150 Yuan/ha. The total saving with SRI methods thus amounted to about 1 565 Yuan/ha. Add to that a 15 percent increase in yield (1.5 tonnes/ha) and the farmer gets a total additional profit of about 3 000 Yuan/ha (about US\$360).

The Sichuan Academy of Agricultural Sciences has done SRI trials for three years in succession. Its 2003 trials showed an average SRI yield of 13 t/ha. Another series of trials in 7 regions of Zhejiang Province using 8 varieties all resulted in increased yield under SRI; the average increase being 1.5 t/ha over already high-yielding controls.

The China National Hybrid Rice Research and Development Centre introduced hybrid varieties into Africa and recommended that they be used with SRI methods. In 2003, a 9.2 t/ha yield was obtained with hybrid GY032 in Guinea under SRI methods, which was four times the national average yield.

SRI in Gambia

The Gambia, a small country (11 700 km²) in West African, is a 50 km-wide ribbon of land extending eastward from the coast, bisected by the River Gambia and surrounded on three sides by Senegal. Its annual rainfall is 900 to 1 400 mm; the rainy season between late May and early October. Rice is the staple of the country and there are 5 very different production systems: upland, lowland rainfed, irrigated (pump and tidal), freshwater swamps and seasonally saline mangrove swamp.

Annual rice consumption averages 70 to 110 kg per capita; domestic production lags behind by 60 percent, and the balance is met by imports. The national average yield of rice is only 2 t/ha.

SRI was introduced to The Gambia in the rainy season of 2000 as part of the Ph. D. thesis of Mustapha M. Ceesay in Crop and Soil Sciences at Cornell University in the United States. Farmers were invited to visit the first SRI trial site at the Sapu station of the National Agricultural Research Institute (NARI) in The Gambia before they enrolled voluntarily in the research programme.

During the first year of experimentation, three different plant population densities were investigated with several varieties. Yields ranged from 5.4 to 8.3 t/ha. In 2001, plant population densities were investigated alongside fertilizer treatments, and on-farm trials involving 10 farmer households. The on-station SRI trials were conducted under pump irrigation, and on-farm trials under tidal irrigation.

Plant population densities investigated were 20 cm x 20 cm, 30 cm x 30 cm and 40 cm x 40 cm. Two rice varieties were used, and instead of compost, three fertilizer treatment rates were assessed: NKP in the following proportions: 70-30-30 (national recommended), 140-30-30 and 280-30-30. All trials took place in the lowland.

The on-station trials indicated that 30 cm x 30 cm spacing did not decrease yield over the 20 cm x 20 cm, and was hence recommended to the farmers for the on-farm trial. Fertilizer treatments indicated that under SRI, the nationally recommended lowest rate was as effective as doubling the rate, while tripling the rate gave higher yields, but it was not economically profitable.

The on-farm trials, conducted in a communal tidal irrigation scheme, gave "exciting" results, "a tripling of yield" on average, 7.4 t/ha compared with 2.5 t/ha obtained with farmers' current practices. Some farmers experienced more than five-fold increases, from 1.6 to 9.0 t/ha in one case, and 1.4 to 8.0 t/ha in another.

But there are problems facing the farmers in land preparation. Farmers in The Gambia still do not have a well-developed culture of water control. Fields are simply kept flooded after transplanting until the rice plants mature, and fertilizer application and weeding are done under submerged conditions. These practices will conflict with the adoption of SRI, but the yield increases may be a sufficient incentive for farmers to overcome these problems.

SRI in other countries

Many countries reported remarkable increases in yield. Salinda Dissanayake, Member of Parliament in Sri Lanka, personally tested SRI in his own rice field of a little more than 2 acres for four seasons, using seeds of various varieties. He got the highest yield of 17 t/ha with BG358, a variety developed by the Sri Lankan rice researchers. Even with local varieties such as Rathhel and Pachdhaiperumal, usually much lower yielding at ~2 t/ha, impressive yields of 8 t/ha and 13 t/ha were obtained.

The on-farm trials gave "a tripling of yield", on average, 7.4 t/ha compared with 2.5 t/ha obtained with farmers' current practices

Dissanayake formed a small group to inform farmers of SRI; and farmers who took up SRI from 18 districts have doubled their yields on average.

"These yields were obtained with less water, less seed, less chemical fertilizer, and less cost of production per kilogram ... among SRI users, we find people of many different income and educational levels and different social standing, including many poor farmers having only small plots of land, farmers with moderate income, some agricultural scientists, and a few administrators, businessmen and political leaders who practice it with their own convictions." Dissanayake said.

H. M. Premaratna, a farmer from the Ecological Farming Centre, Mellawalana, Sri Lanka, backed up the enthusiasm of his Member of Parliament, and has personally provided training on SRI to more than 3 000 farmers by 2002. "From my experience, I have observed that the rice plant becomes a healthier plant once the basic SRI practices are adopted," he said.

Reports from 17 countries in 2002 showed that three-quarters of the cases gave a significant yield advantage of at least 20 to 50 percent increase, and although the super-yields reported from Madagascar have not been obtained elsewhere, some farmers in Cambodia and Sri Lanka have come close. Overall, the conventional systems yielded 3.9 t/ha, very close to the world average for rice production. The average for all the SRI yields reported was 6.8 t/ha.

A report from the Philippines not only documented yield increases over several successive growing seasons since 1999, but also a reduction of crop pests such as rats and brown and green leafhoppers, carriers of the dreaded rice tungro virus disease. This was attributed to the increased spacing of plants, allowing more sunlight to penetrate even the base of the plant, exposing the hoppers, which detest and avoid sunlight.

In Cambodia, SRI was spreading very rapidly. Only 28 farmers were willing to try SRI in 2000, by 2003, this number had grown to almost 10 000 and in 2004, 50 000 farmers were expected to adopt it.

Less is More for Nepali Rice

Between 2002-2005, a dozen farmers in Morang District near the Nepali-Indian border 300 miles south of the capital Kathmandu tested SRI [3]. Using only a fraction of the normal amount of local *mansuli* variety rice seed and far less water than usual, their yield has more than doubled.

Farmer Dan Bahadur Rajbansi was transplanting his rice seedlings using the system of rice intensification as many others delayed planting while awaiting a late monsoon. Ananta Ram Majhi, another of Morang district's rice farmers, admitted he was sceptical. "Initially, I thought to myself, if this is such a great idea why didn't my ancestors think of it? But I decided to take the chance and this is my third year using the new method." Majhi, who used to harvest five tonnes per hectare and was now getting at least twice as much, had achieved this yield with only one-third of the seed he used before, and with less water.

Local agriculture officer Rajendra Uprety first read about the technique on the Internet and decided to try it. "Since 2002, we've achieved double and triple harvests on test plots. It's just amazing." He said.

News of the bumper harvests spread quickly from Morang where about 100 farmers were using the new method. Uprety, who brings farmers from other districts on inspection said "it has been more difficult convincing the agronomists and officials than the farmers".

Scientists remain sceptical

By 2005, SRI had been tried and tested by many thousands of farmers in about 20 countries, from Cuba to China. Tens of thousands of farmers have adopted the method in the few years since researchers introduced it to Cambodia in 2001. And there, as in India, Laos, and Sri Lanka,

farmers are reporting that SRI means bigger harvests and better incomes for fewer seeds and less water.

But critics maintain that the scientific evidence for such claims is lacking because most field trial results have not been recorded in detail and published in peer-reviewed journals. When researchers at the International Rice Research Institute (IRRI) and colleagues tested SRI in field trials in China, they found no difference in yield between SRI and conventionally-grown rice. Their study, published in *Field Crops Research* in March 2004, concluded that: "SRI has no major role in improving rice production generally" (but see Chapter 28).

IRRI prefers high input agriculture

But perhaps IRRI has no interest in low input farmer friendly agriculture. IRRI is the world's leading international rice research and training centre and describes itself as an "autonomous, nonprofit institution" that is "focused on improving the well-being of present and future generations of rice farmers and consumers, particularly those with low incomes." It is also part of the Consultative Group on International Agricultural Research (CGIAR) an association of public and private donor agencies that funds 16 international research centres [4].

Both IRRI and CGIAR have come under criticism for supporting a corporate agenda, for example by breeding high yielding rice varieties, that have caused the loss of over 100 000 local varieties, and that rely heavily on chemical inputs and frequent irrigation. Indigenous varieties capable of giving a higher yield were deliberately excluded from these programmes.

IRRI's annual reports from 1963-1982 show grants from a whole array of US and European



chemical corporations including Monsanto, Shell Chemical, Union Carbide Asia, Bayer Philippines, Eli Lilly, Occidental Chemical, Ciba Geigy (later part of Novartis Seeds which is now part of Syngenta), Chevron Chemical, Upjohn, Hoechst, and Cyanamid Far East.

While farmer dependency on expensive external inputs has increased hugely, yields from Green Revolution cultivation have been in wide decline or are stagnating. Since 1990, the focus at IRRI has been on developing GM rice, another technology aimed at making profit for agribusiness at the expense of people and the environment.

At CGIAR's Annual General Meeting in 2002 near the IRRI in the Philippines, farmers protested calling for both institutions to be dismantled. The protesters issued a statement saying "We believe that a genuine, farmer-centred research institution should develop technologies that shall liberate farmers from dependence on any agro-chemical TNC, promote sustainable agriculture, conserve the environment, and protect the health of farmers."

Trainers spread the word

For Rajendra Uprety in Nepal, the results of SRI speak for themselves. He pointed out that the technique's success depends on skilful farming, good timing, and careful planting and drainage. As planting in flooded paddy fields helped to control weeds, the drier SRI fields need weeding several times during the growing season. But the benefits far outweigh these obstacles, he says, adding that the main challenge is training.

Uprety has turned local farmers like Kishore Luitel into total converts and then into trainers.

Luitel pointed to his own field where rice grew in thick tufts with more than 80 shoots from one seed. "Using the old method, you plant three or four seedlings in one spot and you only get about ten shoots per seed," he says.

Uprety and Luitel were convinced that no part of Nepal has to be short of food anymore if SRI were promoted nationally. Every year, Nepal needs to produce more than 90 000 tonnes of rice seeds. The SRI advocates said the method would save 80 000 tonnes of rice in seeds required for the next planting, and harvests nationwide could be doubled.

In October 2007, WWF released a report [5], which documented that SRI has increased yields by more than 30 percent at four to five tonnes per hectare from three tonnes per ha, while using 40 percent less water. It suggests that the major rice producing countries such as India, China and Indonesia, convert 25 percent of their current rice cultivation to SRI by 2025. This would not only greatly reduce the use of water, but also help ensure food security. Furthermore, it would significantly reduce methane emission, as in contrast to conventional flooded fields SRI fields do not emit methane.



Comparing SRI and conventional rice plant in Indonesia

- 17 -

Brother Paul's Organic Cotton and Vegetable Farm

Jesuit brother broke all the rules he learned in agricultural college and showed how to bring food security to the world



Organic cotton is possible and highly profitable

Brother Paul Desmarais of the Kasisi Agricultural Training Centre of Lusaka in Zambia was a happy man. He had just demonstrated that cotton can be grown organically, and furthermore, at yields up to more than twice the national average. That is quite an achievement as cotton is notorious for consuming the most agrochemicals of any crop, some 21 percent of that consumed worldwide; and most people have been led to believe that cotton cannot be grown without chemical sprays (see Chapter 21).

"I am confident that anyone can grow cotton organically in Zambia", says Br. Paul, beaming from ear to ear. You need to do only two things: increase the fertility of the soil with organic matter, and put extra local plant species into the cotton

fields to control insect pests." This has been independently confirmed in Andhra Pradesh in India (Chapter 14).

Plants that are sick or doing poorly will be the first to succumb to insect pests; so keeping a crop healthy with fertile soil reduces insect attacks. But skilful inter-planting with a variety of insect attracting and trapping local plant species accounts for a lot of the success here as in India.

The species inter-planted with the cotton crop are those that attract pests away from the cotton crop or beneficial predators, or provide home for beneficial predators; many species serving both purposes. For example, *munsale* (sweet sorghum) attracts bollworm and aphids as well as a host of beneficial insects; *nyemba* (cowpeas) provides a habitat and food source for ants and predatory wasps, and also attracts the pests leafhoppers,

aphids and bollworms; *sanyembe* (sunhemp) is highly attractive to beneficial insects as a border crop and controls nematodes as well. Delele (okra) attracts bollworms, caterpillars and leaf eaters; *milisi* (maize) traps aphids on tassels and bollworms; *mupilu* (mustard) attracts beneficial hover flies and parasitic wasps as well as aphids on which they feed. Malanga (sunflower) attracts bollworm moths to lay eggs, and the beneficial lacewings that feed on aphids. A horizontal row containing a mixture of all these were planted for every 20 rows of cotton in the field bordered by sunhemp on two sides. A host of other species can be planted, adding to the diversity of the farm.

A variety of trees, such as *Sesbania*, *Leucaena*, and other indigenous species can act as windbreaks and provide habitat for farmers' friends and provide material for composting and making teas.

The experiments started in 2003/04 in the Kasisi Centre, and in farmers' fields in Chongwe district (see Table 17.1). The yields are calculated per 0.25 ha in the first instance to make the different size plots comparable. The two grades were from one harvest and refer to the quality of the cotton. The cotton companies pay more for grade A and less for grade B, and still less for grade C. The yield in KATC was twice the national average. Good yields were also obtained in the farmers' plots in Lusoke and Mulalika. In Old Kasenga and Ndubulula, the poor yields were due to insufficient weed control and late planting respectively.

Area	Yield (kg)			
	Grade A	Grade B	Total	kg/ha
KATC	215	144	359	1 436 ¹
Old Kasenga	85	25	110	440 ²
Lusoke	185	100	285	1 140
Mulalika	220	230	250	1 000
Ndubulula	72	23	95	380 ³

1. Twice the national average for conventionally grown cotton, which was 600 kg/ha according to the Zambian government, and 653 kg/ha according to the cotton company Dunavant.
2. Poor weed control
3. Late planting

Table 17.1. Yield of organic cotton in 2003/04

The economics of organic cotton from the KATC was compared with that of conventional cotton in the villages (Table 17.2). As can be seen, the net profit from organic production was more than twice that of conventional. The organic plots not only gave higher yield in the main cotton crop, they also provided harvests from the inter-planted species that could be sold.

The input costs for the organic plots were higher due to the extra labour and costs of preparing composts and manure teas. Less cottonseed is used in the organic fields due to inter-planting, but the yield was still higher. If the cotton were sold on the organic market, it would fetch a premium and increase income still further for the household.

In the following year, 2004/05, only grade A

Item	Organic (KATC)		Conventional (in villages)	
	Quantity	Kwacha	Quantity	Kwacha
Cotton	359 kg	482 100	256.0 kg	363 520
Okra	3 kg	4 500	2.5 kg	3 750
Cowpeas	10 kg	18 000		
Maize	97 kg	69 840		
Sorghum	50 kg	25 000		
Sunflower	5 kg	8 000		
Total Income		617 440		367 270
Input				
Land Preparation				
Ripping		2 750		2 750
Marking lines		16 500		16 500
Planting:				
Cottonseed	2.5 kg	5 367	3.0 kg	7 000
Interplants seed		15 000		
Planting labour		10 000		8 250
Hand weeding		16 500		16 500
Crop nutrition:				
Compost + teas		88 000		
Solubor				7 500
Chemical				30 000
Scouting		32 000		32 000
Spraying labour				8 250
Harvesting labour		49 500		49 500
Total		235 617		178 250
Net profit		381 823		189 020

*The exchange rate is about 4 500 Kwachas for one US dollar.

Table 17.2 Comparing the economics of organic and conventional cotton in 2004

cotton was harvested. The yields went down because of the poor rainy season (see Table 17.3); but they were still better than the conventional national average for that year, which was 580 kg/ha. The seed cotton was tested for staple length, strength, etc., and the results were slightly better than most conventionally grown seed cotton samples. So even with the lower prices paid that year (as market price had gone down), farmers were still able to record a profit because of the lower input costs.

Area	Yield kg	100 Kg/ha
KATC		
Old Kasenga	210	
	186	840
	152	744
	80	608
	85	320
	180	340
Lusoke	205	720
Mulalik	187	820
	195	748
Nikubulula	145	780
	195	580
	102	195
Kankantapa	186	408
	185	744
Chinkuli	110	740

Table 17.3. Yield of organic cotton in 2004/05

Organic vegetables that increased in yield year by year

Kasisi has actually been growing organic vegetables several years before, and the results are even more stunning. Land was contracted out to a company which started growing in 2000, the organic yields were 40 to 60 percent those of conventionally grown crops, but increased in successive years while those of convention crops decreased. By 2004, the organics were out-yielding the conventionals by 2 to 3 fold (see Table 17.4).

Cotton can be grown organically, and furthermore, at yields up to more than twice the national average

Crop/Year		2000	2001	2002	2003	2004
Fine beans	Organic	6 290	6 290	7 980	10 450	12 200
	Conven	10 980	12 350	8 900	8 000	6 400
Baby corn	Organic	4 500	5 000	7 800	9 800	10 000
	Conven	11 900	11 000	8 900	8 000	7 000
Peas	Organic	6 000	8 000	12 000	15 000	15 000
	Conven	12 000	12 000	8 000	6 000	4 500

Table 17.4. Average yields(kg/ha) for organic and conventionally grown vegetables

While yield increased year by year under organic management, production costs decreased (Table 17.5), partly on account of setting up costs during the first year, such as liming and rock phosphate amendments, and partly because the labour required for pest control diminished as soil fertility and plant health improved from compost and green manure, and the organic integrated pest management regime became more mature and effective in preventing pest attacks. The carrot crop was introduced when the soil fertility had already been built up, so there is little or no difference in production costs over the three successive years.

Plants that are sick or doing poorly will be the first to succumb to insect pests; so keeping a crop healthy with fertile soil reduces insect attacks. But skilful inter-planting with a variety of insect attracting and trapping local plant species accounts for a lot of the success

Crop	2000	2001	2002	2003	2004
Baby Corn	1 211	1 192	846	630	599
M tout	2 403	2 383	1 583	1 386	1 256
Beans	2 618	2 592	1 664	1 506	1 264
Chili	2 613	2 547	1 892	1 712	1 500
Carrot			1 112	1 116	1 012

Table 17.5. Production costs(in US\$) of organic vegetables over a five-year period

Farmers' own open pollinated varieties outperform commercial hybrids

Hybrid seeds are sold by companies for their potential to give higher yields than non-hybrid seeds. But because they do not breed true, farmers must purchase the seeds from the companies every year if they want to keep up the same performance. In contrast, non-hybrid seeds, or open pollinated varieties, though lower yielding, have allowed the farmers to save and replant seeds every year. That is what every student of agriculture and genetics has been told, and it has become a dogma among academic plant scientists that open pollinated varieties can never yield as much as hybrids.

Br. Paul proved them wrong. Open pollinated varieties (OPVs) of maize, obtained from local small-scale farmers who have been saving them for years, gave yields equal or better than some commercial hybrid varieties grown under the same organic management regime. Table 17.6 shows the yields of OPV and hybrid maize under organic management.

The high yields from OPVs show that they perform better in low external input systems, as opposed to hybrids that require high external inputs to fulfil their high yielding potentials. That is good news for small-scale farmers, not only in providing food security, but also the right to save, exchange and replant their own seeds, which they have had for millennia, instead of depending on the companies, and worse, in the case of GM crops, pay extra "technology fees".

"We are told that hybrid maize seeds will yield three times as much as the OPVs." Br. Paul said, "But one member of staff at Kasisi last year planted an OPV maize variety using compost and manure teas as fertiliser. Well he has been able to sell his surplus maize to his neighbour who planted hybrid maize seed and used fertiliser. Who has food security?"

"Some farmers do even better. Another family went into organic production since 1998, and has been able to buy a donkey, a bicycle, roofing sheets, a colour TV, a maize grinding mill, and pay for the university fees of a daughter." Br. Paul continued, "They were able to feed themselves when they farmed conventionally, but never had any money left over. They produced food for the house and managed to repay the fertilizer loan, but after going into organic production, they have much more money at their disposal."

Unlearning his lessons at university

Br. Paul was raised on a farm in Southwestern Ontario in Canada, one of the most productive farming areas in the country. He says, "My dad used a lot of fertilisers and chemicals. We were modern farmers like many others in the area, quick to adopt new technologies, using more and more fertilisers every year, applying herbicides and spraying for pests in large tomato field."

Br. Paul majored in plant pathology while studying for his agricultural degree, his studies were focussed on the Green Revolution. He confesses, "When I came to Zambia, I naively thought that I would change things here. During

the first 15 years, I promoted the use of fertiliser, chemical spraying in the vegetable gardens and using hybrid seed. It finally dawned on me that we were not going anywhere. Every year farmers were asking for loans to buy seed and fertiliser. Farmers made some money on maize production in only two years out of those 15 years."

As he looked round, he realized it was not only at Kasisi and in Zambia, or Latin America that farmers were doing poorly. It was the same in Europe and North America. "In North America, farmers I knew personally have gone bankrupt. They would have been considered role-model farmers, doing everything according to the advice given by the government agricultural extension officers and agricultural universities. But they went bankrupt and lost their farms. The excuse offered was that inefficient farmers were being weeded out."

In Zambia, 80 percent of the rural population are poor. Many farmers cannot even produce enough food to feed their own families. They are continually asking for loans to buy farming inputs. Fertilisers arrive late, if at all in the villages. Now, they have been advised to add an equal amount of lime to the fertilizer.

Transport is a big problem; there are virtually no roads for vehicles in remote areas. To make things worse, a fuel crisis had taken over the country in the past weeks and everywhere you go, long queues for petrol snaked towards empty petrol stations waiting for promised deliveries.

In the 1980s, someone suggested to Br. Paul that he should look at organic agriculture, but he thought it was strictly for a small left-wing group

Crop	Yield kg/lima (0.25 ha)
Late maturing OPV	1 400
Late maturing	1 238
Late maturing OPV inter-planted with sorghum	1 248
Late maturing hybrid inter-planted with sunhemp	1 044
Medium maturing hybrid	1 375
Short season hybrid inter-planted with sunhemp	825

Table 17.6. Comparing OPV and hybrid maize under organic management

who had enough money to pay for this type of farming. Nevertheless when he returned for home leave in Canada in 1988, he visited organic farmers, and found them to be successful. He studied the principles of organic agriculture in Ontario and adapted them to the situation in Zambia, and has never looked back.

"The staff at KATC, once convinced of the organic way of farming and the value of indigenous knowledge, have been very much in the forefront in explaining this to their fellow country folk." Says Br. Paul.

The Kasisi Agricultural Training Centre trains small-scale farmers in 5-day residential courses on the principles of organic agriculture and indigenous knowledge, on organic vegetable production, organic cotton production, internal control systems, farm management, beekeeping, agroforestry, seed multiplication on farm and dairying.



Br. Paul with handmade bricks that require no mortar

Environmental and Health Benefits

- 18 -

Cleaner Healthier Environment for All

Organic agriculture greatly reduces environmental pollution from nitrates and pesticides, increases agricultural and natural biodiversity, improves health for plants, animals and people, and urgently needed for saving the honeybee



Lichens are a sign of unpolluted environment

The environmental and health impacts of conventional agriculture are well known and widely accepted. Jules Pretty at Essex University in the UK had estimated that pollution of water, soil erosion and loss of natural habitat cost the UK £2.34 billion just in the year of 1996 [1]. The contamination of drinking water cost £120 million for pesticides, £16 m for nitrates, £23 m for Cryptosporidium and £55 m for phosphate and

soil; it cost £124 m for damage to wildlife, habitats, hedgerows and drystone walls, £1 113 m for emissions of gases, £96 m for soil erosion and organic carbon losses, £169m for food poisoning, and £607 m for BSE. This was a conservative estimate, and did not include the costs of chronic pesticide damage to human health, for example. The environmental and health cost of pesticides was estimated at £12 billion a year in the United



States (see Chapter 13).

In this chapter, we review some relevant findings on the environmental benefits of organic agriculture that arise from eliminating pesticides and artificial fertilizers, and from other practices integral to organic sustainable agriculture.

Less chemical input, less leaching and run-off

Large amounts of artificial fertilizers are applied to soils in conventional farms. Nitrates and phosphates leach from the soil or run off to contaminate ground and surface water, causing excessive plant growth or eutrophication in lakes, estuaries, or slow-moving streams, which reduce oxygen in the water and encourage the growth of toxic bacteria that kill fish and other aquatic species. Nitrate is a recognized health hazard [2]. It is responsible for methaemoglobinaemia, or blue baby syndrome, when nitrite, formed from ingested nitrate, combines with haemoglobin to make methaemoglobin, which is not effective in carrying oxygen. Nitrate in drinking water has also been associated with hyperthyroidism, with increased risk for central nervous system malformations in the newborn, genotoxic effects, insulin-dependent diabetes, and cancers of the stomach or bladder, through the evidence for cancers is conflicting.

Nitrogen fertilizers are also a major source of nitrous oxide (see Chapter 19), a serious greenhouse gas with global warming potential 300 times that of carbon dioxide.

A 21-year study in Switzerland [3] assessed the extent to which organic farming practices would affect the accumulation of total and available phosphorus (P) in soil, compared to conventional practices [4]. Soil samples were taken from a non-fertilised control, two conventionally cultivated treatments and two organically cultivated treatments. The researchers found that the average annual P budgets of both organic farming systems were negative, which indicated that P removal by harvested products exceeded the P input by fertilisers. In contrast, the

conventionally cultivated soil, receiving both mineral fertilisers and farmyard manure, showed a positive budget. Furthermore, the inorganic P availability in the topsoil decreased markedly in all treatments during the field trial except in the conventional treatment. Thus, the potential for P pollution from organic systems was reduced.

Another long-term experiment carried out at the Rodale Institute in the United States had earlier found that the conventional system had 60 percent more nitrate leached into groundwater over a five-year period than the organic systems [5, 6].

Organic agriculture uses organic wastes and compost to fertilize the soil, and is a means of recycling nitrogen-containing nutrients, thereby reducing both N inputs into the biosphere and dependence on fossil fuels. Synthetic fertilizers add N into the soil, and fossil fuels are consumed in their manufacture and transport.

A team of scientists led by Sasha Kramer of Stanford University California in the United States investigated nitrogen balance in organic, integrated and conventional apple orchards [7].

Nitrous oxide N_2O is produced from nitrate by denitrifying bacteria in the soil. In most natural systems, most of the gas produced during denitrification is fully reduced nitrogen N_2 , a nonreactive and environmentally benign major component of our atmosphere. However, a variable proportion escapes as N_2O before being fully reduced. In agricultural systems, N_2O emission is enhanced after fertilization.

In their study, the scientists compared denitrifying function and N leaching in soils from organic, integrated and conventional plots. They found that the organic plots had the highest amount of total soil N at 1 955 ppm (parts per million), compared to 1 755 ppm in integrated plots and 1 242 ppm in conventional plots. Organic plots also had the most active denitrifying function, measured as denitrifying potential at 113.92 units (mmol of N_2O per h per g of soil), nearly 10 times that of the conventional soil at 12.21 units, while the integrated soil was 40.39 units.

Correspondingly, the organic soils had the greatest microbial biomass of 512.7 mg C per kg of soil, compared to 420.8 mg in the integrated soils and 357.7 mg in the conventional soils. The microbial communities were different among the different soils. In laboratory tests, the organic soils were indeed found to be the most efficient in denitrification.

Tests were carried out in the field to detect the relative amounts of N_2 and N_2O gases going into the atmosphere and nitrate leaching from the soil after the conventional plots were fertilized with $Ca(NO_3)_2$, the integrated with equal parts of chicken manure and $Ca(NO_3)_2$, and the organic with either chicken manure or alfalfa meal. The amount of nitrogen was adjusted to be equal in all the fertilizer treatments. For a month after the fall fertilizations the total amount of N_2O emissions were lower in the organic treatments compared with the integrated or conventional, but were roughly the same among all treatments after the

spring fertilization, and significantly above unfertilised controls. N_2O emissions ranged from 1 to 9 ng N $cm^{-2} h^{-1}$.

However, the amount of nitrate leached from the conventional soil, especially after the spring fertilization was four to six times the organic treatment: 1 002.24 mg N at 100 cm depth compared with organic soils, manure fertilized at 180.13 mg N and alfalfa fertilized at 234.11 mg N; the integrated fertilized soil had an intermediate value at 608.26 mg N. On a yearly basis, the nitrate leaching from the conventional soils were still four to five times the organic.

Interestingly, N_2 loss rates were significantly higher from both organic treatments compared with the conventional treatment, confirming that the organic soils were more efficient at denitrification, converting much more of the nitrates into N_2 relative to N_2O . The increased N_2 released into the atmosphere is consistent with the reduction in nitrate leaching into ground water.

Thus organic farming and to some extent integrated management can improve the denitrifying functions of soil, reducing nitrate pollution to a fraction, improving the quality of our drinking water and saving numerous aquatic species from decimation.

Avoiding pesticides without increasing infestation

Organic farming prohibits routine pesticide application, which have many harmful effects on wildlife and people. According to the Soil Association, 447 synthetic pesticides are allowed in UK non-organic farming [8], including organophosphates that have been linked with cancer, male infertility, foetal abnormalities, chronic fatigue syndrome in children and Parkinson's disease.

Organic farming avoids the use of synthetic pesticides altogether, or use only a few as a last resort: seven permitted in the UK, and only 4 in organic farms certified by the Soil Association. These are either of natural origin (rotenone and soft soap) or simple chemical products (copper compounds and sulphur). Some 10 tonnes of pesticides are used on Soil Association organic farms a years, compared to a total of 31 000 tonnes in the UK as a whole.

Organic farmers generally rely on a number of other means to control pests including crop rotation, maintenance of biodiversity to encourage natural predators, mixed cropping, biological control, and the maintenance of a healthy soil (see many chapters in this volume)

Research in Californian tomato production [9] found no significant difference in levels of pest damage in 18 commercial farms, half of which were certified organic systems and half, conventional operations. Arthropod biodiversity was on average one-third greater in organic farms than in conventional farms. There was no significant difference between the two management systems in pest abundance. However, the natural enemies of pests were more abundant in organic farms, with greater species

richness of all functional groups (herbivores, predators, parasitoids). Thus, any particular pest species in organic farms would be associated with a greater variety of herbivores (i.e. would be diluted) and subject to control by a wider variety and greater abundance of potential parasitoids and predators.

On a yearly basis, the nitrate leaching from the conventional soils were four to five times the organic. The organic soils were more efficient at denitrification, converting much more of the nitrates into N_2 relative to N_2O

Other research shows that it is possible to control pests without pesticides, and actually reverse crop losses. In East Africa, maize and sorghum face two major pests, the stem borer insect and Striga, a parasitic plant. Field margins are planted with 'trap crops' that attract stem borer, such as Napier grass and Sudan grass. Napier grass is a local weed whose odour attracts the stem borer. Pests are lured away from the crop into a trap, as the grass produces a sticky substance that kills stem borer larvae [10]. The crops are inter-planted with molasses grass (*Desmodium uncinatum*) and two legumes: silverleaf and greenleaf. The legumes bind N, enriching the soil, while Desmodium also repels stem borers and Striga.

In Bangladesh, a project began in 1995 to promote non-chemical pest control in rice that relies on natural enemies and on the ability of the rice plant to compensate for insect damage. There have been no negative impacts on yields [11]. On the contrary, farmers using no insecticide consistently had higher yields than those using insecticide. Project participants also earned more than insecticide users: the 1998 average net return for participants was Tk5373 (US\$107) per farmer per season compared to Tk3 443 (US\$69) for insecticide users.

Besides the obvious benefit of not using harmful pesticides, Korean researchers found that avoiding pesticides in paddy fields encouraged the mud loach fish, which effectively control the mosquitoes that spread malaria and Japanese encephalitis [12]. Fields in which no insecticides were used had a richer variety of insects, but the fish are voracious predators of mosquito larvae.

In Japan, an innovative organic farmer pioneered a rice growing system that turns weeds and pests into resources for raising ducks, which also benefited the rice plants by providing mechanical stimulation, aeration and nutrients (see Chapter 27).

For the health benefits of avoiding pesticides and other health benefits of organic agriculture, see Chapters 20 and 21.

Greater biodiversity

Organic agriculture is good for natural biodiversity both above and below ground, simply by avoiding the use of toxic agrochemicals and reducing pollutants from chemical fertilizers. More importantly, organic farmers often make use of natural and agricultural biodiversity as means of pest control.

Research carried out in Colombia and Mexico



Saving the honeybee may be the most compelling reason for shifting promptly and comprehensively to organic agriculture worldwide

found 90 percent fewer bird species in sun-grown coffee plantations as opposed to shade-grown organic coffee, which mimics the forests' natural habitat [13]. Shade cultivation is recommended by organic standards as it enhances soil fertility, controls pests and diseases and expands crop production options.

A review by the Soil Association in 2000 [14] concluded that organic farming in the lowlands supports a much higher level of biodiversity (both abundance and diversity of species) than conventional farming systems, including species that have significantly declined. This was particularly true for wild plants, birds and breeding skylarks, invertebrates including arthropods eaten by birds, non-pest butterflies, and spiders. Organic farms also showed significantly less pest aphids and no change in pest butterflies. Habitat quality was more favourable on organic farms, both in terms of field boundaries and crop habitats. Many beneficial practices were identified in organic agriculture, such as crop rotations with grass leys, mixed spring and autumn sowing, more permanent pasture, no application of herbicides or synthetic pesticides, and use of green manure. These practices can reverse the trends in the decline of biodiversity associated with conventional farming. Generally, the improvements in biodiversity were found across the cropped areas as well as at the field margins. The report also suggested that major benefits are likely in the uplands.

A comprehensive review of 76 comparative studies published in 2005 [15] found similar results overall. There was greater species richness and abundance across many groups of plants and animals in organically managed fields than conventional fields. The clearest differences were

found for birds: twice as many species of birds on organic farms and 2.6 times the abundance compared with conventional farms. There were higher densities of skylarks and blackbirds. One study found 31 species significantly more abundant on organic farms, including the lapwing, the linnet and corn bunting. A greater abundance and diversity of many invertebrate and plant groups in organic farms was highlighted as the principal reason for the difference in the abundance and species richness of birds. There were more weeds and weed species, more carabid beetles, spiders and other arthropods, more butterflies, earthworms, more nematodes, and greater bacterial and fungal biomass in the soil of organic fields.

The reduced or non-use of agrochemicals in organic and sustainable farming will allow wild plant species to flourish, among which are herbs used in traditional medicines. The World Health Organisation estimates that 75-80 percent of the world's population use plant medicines either in part or entirely for health care. Some of these wild plant species are facing extinction, and concerted effort is needed for their local conservation, while ensuring that harvesting from the wild is sustainable and continues to contribute to local people's livelihood [16]. Wild plants and animals are an important part of the repertoire of food and medicines for many farming communities [17].

Saving the honeybee

Honeybees have been disappearing worldwide at an alarming rate. Across the United States in 2006 to 2007, beekeepers were losing 30 to 90 percent or more of colonies in a "colony collapse disorder" (CCD) that's causing huge economic losses not only to beekeepers but also to fruit and vegetable growers [18]. CCD has been reported in Germany, Switzerland, Spain, Portugal, Italy, Greece, and the UK in Europe, and even in Australia. Many believe that when the honeybee disappears, our species' demise will not be far behind.

ISIS has reviewed the evidence extensively, and among the most important single factors identified as major contributors to CCD are sub-lethal levels of insecticides [19], in particular, a class of new systemic neonicotinoid pesticides widely used in seed dressing and crop sprays. Sub-lethal levels of pesticides, including the Bt biopesticides produced in genetically modified (GM) crops covering some 30 percent of the global GM crop area, disorientate the bees, making them behave abnormally, and compromise their immunity to infections.

There is also evidence that sub-lethal levels of neonicotinoid pesticides, particularly imidacloprid, act synergistically with parasitic fungi such as *Nosema* in killing insects pests [20]. The parasitic fungal spores, extensively used as biocontrol agents, are applied in sprays and baits, and when delivered in suspension with sub-lethal levels of pesticides, are much more effective in killing insects.

Equally, Bt biopesticides greatly enhance the killing power of parasitic fungi synergistically.

There is every reason to eliminate the use of all pesticides that act synergistically with parasitic fungi, and all Bt crops should be banned for the same reason.

Agricultural biodiversity crucial for food security and conservation

Maintaining agricultural biodiversity is vital to long-term food security [17]. It contributes to efficient production, environmental sustainability and rural development; and regenerates local food systems and rural economies. Rural people have dynamic and complex livelihoods, which usually rely on a diversity of plant and animal species, both wild and domesticated. Diversity *within* species (i.e. farmers' varieties or landraces) is also remarkable among domesticated crops and livestock. These indigenous varieties are adapted to different microhabitats and microclimates, and are important for spreading the risks of crop losses extremes than the monoculture Green Revolution HYVs that have replaced them, with disastrous consequences for farmers (see Chapter 2).

A 2002 FAO conference highlighted the intimate relationship between biodiversity and the ecological approach to agriculture [21]. One paper reviewed 16 case studies from 10 countries in Asia, Latin America, Europe and Africa, showing how organic farming increases the diversity of genetic resources for food and agriculture [22]. In all cases, organic systems involved the maintenance of biodiversity,

resulting in improving the farmers' socio-economic conditions.

Case studies of a community-based organic farming system in Bangladesh, the ladang cultivation of organic spices in Indonesia, and organic coffee production in Mexico show how traditional and community-based management can rehabilitate abandoned and degraded agro-ecosystems. These diverse polyculture systems are set within highly diverse ecosystems that provide food and other community services. Organic cocoa farming in Mexico, and organically farmed naturally pigmented cotton in Peru, are examples of agro-ecology that have contributed to *in situ* conservation and sustainable use of natural resources in centres of diversity, while providing economic benefits for local communities. Traditional, under-utilised species and varieties in Peru (gluten-free quinoa), Italy (Saraceno grain, Zolfino bean, spelt wheat) and Indonesia (local varieties of rice) have been rescued from extinction, thanks to organic agro-ecology. Similar organic farming projects in Germany, Italy, South Africa, and Brazil, have restored many traditional varieties and breeds that are better adapted to local ecological conditions and resistant to disease.

Biodiversity is an important, integral part of sustainable agriculture. Each species in the agro-ecosystem is part of a web connected by flows of energy and materials and symbiotic, reciprocal relationships [23]. Different components of agrobiodiversity are



Flowering crop planted under orchard increases biodiversi-

multifunctional, and contribute to the resilience of production systems as a whole while providing environmental services, although some species may play key driving roles [19]. The environmental services provided by agricultural biodiversity include soil organic matter decomposition, nutrient cycling, biomass production and yield efficiency, soil and water conservation, pest control, pollination and dispersal, biodiversity conservation, climate functions, water cycling, and influence on landscape structure.

Empirical evidence from a study conducted since 1994 shows that biodiverse ecosystems are two to three times more productive than monocultures [24, 25]. In experimental plots, both aboveground and total biomass increased significantly with species number. The high diversity plots were fairly immune to the invasion and growth of weeds, but this was not so for monocultures and low diversity plots. Thus, biodiverse systems are more productive, and less prone to weeds as well.

Proving with stunning results that planting a diversity of crops is beneficial (compared with monocultures), thousands of Chinese rice farmers have doubled yields and nearly eliminated its most devastating disease without using chemicals [26, 27]. Scientists worked together with farmers in Yunnan, who implemented a simple practice that radically restricted the rice blast fungus that destroys millions of tons of rice and costs farmers several billion dollars in losses each year. Instead of planting large stands of a single type of rice, farmers planted a mixture of two varieties: a standard hybrid rice that does not usually succumb to rice blast and a much more valuable glutinous or 'sticky' rice known to be very susceptible. The genetically diverse rice crops were planted in all the rice fields in five townships in 1998 (812 hectares), and ten townships in 1999 (3 342 hectares).

Disease-susceptible varieties planted with resistant varieties had 89 percent greater yield, and blast was 94 percent less severe than when grown in monoculture

Disease-susceptible varieties planted with resistant varieties had 89 percent greater yield, and blast was 94 percent less severe than when grown in monoculture. Both glutinous and hybrid rice showed decreased infection. The glutinous rice plants, which rise above the shorter hybrid rice, also enjoyed sunnier, warmer and drier conditions that discouraged fungal growth. Disease reduction in the hybrid variety may be due to the taller glutinous rice blocking the airborne spores of rice blast, and to greater induced resistance (due to diverse fields supporting diverse pathogens with no single dominant strain). The gross value per hectare of the mixtures was 14 percent greater than hybrid monocultures and 40 percent greater than glutinous monocultures.

In Cuba, integrated farming systems or polycultures, such as cassava-beans-maize,

cassava-tomato-maize, and sweet potato-maize have 1.45 to 2.82 times the productivity of monocultures [28]. In addition, legumes improve the physical and chemical characteristics of soil and effectively break the cycle of insect-pest infestations.

Integrating vegetables into rice farming systems in Bangladesh by planting them on dikes has not affected rice yields, despite the area lost to dike crops [29]. Instead, the vegetables provided families with more nutrients. The surplus was shared with neighbours, friends and relatives or sold, providing an added value of 14 percent. Integrating fish into flooded rice systems also caused no significant decline in rice yields, and in some cases increased yields. Net returns from selling the fish averaged Tk7 354 (US\$147) per farmer per season, more than the returns from rice. As with vegetables, rice-fish farmers ate fish more frequently and donated much of it to their social networks.

Soil biodiversity also plays a crucial role in promoting sustainable and productive agriculture, and organic practices help enhance this [30]. Organic mulch, applied judiciously to degraded and crusted soil surfaces in the Sahelian region of Burkina Faso, triggered termite activity, promoting the recovery and rehabilitation of degraded soils. Termites feeding on or transporting surface-applied mulch improved soil structure and water infiltration, enhancing nutrient release into the soil. The growth and yield of cowpeas were far better on plots with termites than on plots without. In India, organic fertilisers and vermicultured earthworms applied in trenches between tea rows increased tea yields by 76-239 percent, compared to conventional chemical fertilisation. Profits increased accordingly.

Environmentally sustainable

A Europe-wide study assessed environmental and resource use impacts of organic farming relative to conventional farming [31] showed that organic farming performs better than conventional farming in relation to the majority of environmental indicators reviewed. In no category did organic farming show a worse performance when compared with conventional farming. For example, organic farming performed better than conventional farming in terms of floral and faunal diversity, wildlife conservation and habitat diversity. Organic farming also conserved soil fertility and system stability better than conventional systems.

The same conclusion was stated in a FAO review in 2002 [32]: "As a final assessment, it can be stated that well-managed organic agriculture leads to more favourable conditions at all environmental levels" (*italics added*, p.62).

Both the European and the FAO assessments have been amply confirmed since.

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Mitigating Climate Change

Organic, sustainable agriculture that localizes food systems has the potential to mitigate nearly thirty percent of global greenhouse gas emissions and save one-sixth of global energy use



Local fruit and vegetable market in Rome, Italy

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], 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 (see Chapter 5). 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 (Chapter 8).

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 [2]; nor does it mention localising food systems and reducing long distance food transport [3].

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 [4].

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 [5]. Research in Finland showed that while organic farming used more machine hours than conventional farming, total energy consumption was still lowest in organic systems [6]; 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 [7, 8]. Studies in Denmark compared organic and conventional farming for milk and barley grain production [9]. 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 [10], and about 1.8 percent of national greenhouse gas emissions [11] 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 from 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 [12]. 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 [13].

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 [13]. 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 [14]: 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 [15].

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 [14].

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) [16]. The total emissions were 6.1Gt CO₂e, made up almost entirely of CH₄ (3.3 Gt) and N₂O (2.8 Gt). 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 [18], and is comprised entirely of methane at 37.5 percent of national total [19] and nitrous oxide at around 95 percent of the national total (80 000 tonnes) [20]. 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) [21].

Assuming half of all nitrous oxide emissions come from N fertilizers, phasing them out would save 11.56 Mt of CO₂e. 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 (N₂O) [4]. 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 [22], 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



Local food market in Yantai, China

fall, and more active denitrifying in organic soils, which turns nitrates into benign N_2 instead of nitrous oxide and other nitrogen oxides (Chapter 18).

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 [23].

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.

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 [24] 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 [25]. 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 (Chapters 31 and 32).

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 (Chapter 13), and water conservation and management through agriculture will be an increasingly important part of mitigating climate change (Chapters 16, 28 and 33).

Globally, with 1.5335 billion hectares of crop land 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

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 [26] 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 [27]. 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 [28]. After 22 years, the organic farming systems averaged 30 percent higher in organic matter in the soil than the conventional systems (Chapter 13).

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 [29]. 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 [30]. On this basis, a fully organic UK could save 68 Mt of CO_2 or 10.35 percent of its ghg emissions each year. Globally, with 1.5335 billion hectares of crop land [31] 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 [14]: "...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 [14] 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 [32], 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'Etudes de la Pollution Atmosphérique) for France [33] (see Box 19.1).

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 CO₂ 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 [18]; 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 [33].

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

Box 19.1 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 Mt C
Share linked to food system	30.4%

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.

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 relocating food systems.

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

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	4 190

Table 19.1. Energy 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

Table 19.2. Carbon dioxide accounting for 1 kg tomato ketchup

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 19.1 and 19.2), taking the minimum values of energy and emissions costs.

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 (see Chapter 34).

Assuming that it is feasible to reduce the energy consumption and carbon emissions of processing and packaging 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 19.2.

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.

Box 19.2	
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 %

- 20 -

Organic Farms Make Healthy Produce Make Healthy People

Organic foods are richer in minerals, vitamins and antioxidants that protect against cancer and degenerative diseases, and relatively free from harmful chemicals and additives that cause diseases



No BSE in organic herds

"Official: organic really is better" [1], the recent newspaper headline captures what everybody has already known for decades, but certain sections of the scientific establishment, especially the proponents of genetically modified crops, are at pains to dismiss. This new evidence comes from the £20 m four-year study funded by the European Union, which found that organic fruit and vegetables contained as much as 40 percent more antioxidants.

Researchers grew fruit and vegetables and reared cattle on adjacent organic and non-organic

sites in a 725-acre farm attached to Newcastle University and other farms in Europe. They found that levels of antioxidants in milk from organic herds could be up to 90 percent higher than in milk from conventional herds.

UK's Food Standards Agency has dismissed all the evidence submitted to it so far, insisting there is no good scientific evidence that organic food is healthier than non-organic. But it has promised to review the new evidence.

For the rest of us, however, the existing evidence is convincing enough, and it goes back a

long way, before our food has been ruined by industrial agriculture and the entire industrial food system.

The importance of good food and good soil, a page from history

People in the industrialised West rely increasingly on ready-prepared meals and packaged foods. To prolong shelf life, some of the ingredients will have been refined, with the most nutritionally valuable components, such as the germ and bran of grains, discarded, and extra chemicals (additives) put in as preservative, flavouring, or colour. Coincidentally, there has been rising incidence of heart disease, cancers, diabetes, allergies and other disorders. Could there be a connection between diet and disease?

The British doctor Sir Robert McCarrison had asked this question 80 years ago while working in India, and his experience was described in a book by GT Wrench first published in 1938, and reprinted twice since [2]. McCarrison was struck by the marvellous health of certain native peoples, especially those living in Hunza, and wondered why that was the case. (A disheartening footnote must be added to the story of the people of Hunza. Already in the 1930s, with increased exposure to Western ways, their remarkable health had begun to decline.) The natives enjoyed freedom from disease and life-long vitality despite their exceptional longevity. Their healthy mental state was reflected in their freedom from quarrels and exceptionally cheerful disposition.

The Hunzakuts were farmers, cultivating terraced fields. The numerous small fields were irrigated from a glacier. They enjoyed fresh, nutritious and unprocessed foods, and everything that originated from the soil was returned to the soil.

Wrench's book also describes how Sir Albert Howard, Director of the Institute of Plant Industry at Indore, India, followed the ancient Chinese practice of applying manure to crops, which continued to improve as a result. In the seven years Sir Albert was there, he could not recall a single case of insect or fungus attack. The animals feeding on these crops also prospered. He said [3]: "I was able to study the reaction of well-fed animals to epidemic diseases, such as rinderpest, foot-and-mouth disease, septicaemia, and so forth, which frequently devastated the countryside. None of my animals was segregated; none was inoculated; they frequently came in contact with diseased stock. No case of infectious disease occurred. The reward of well-nourished protoplasm was a very high degree of disease

resistance, which might even be described as immunity."

Sir Albert's method of plant breeding was applied on a farm at Surfleet, England, beginning in 1935, and described a few years later [4]: "The results of this Surfleet experiment of but two years' duration have surprised those who have watched it. The vegetables not only have a richer flavour; not only have they a robuster appearance and their leaves a deeper green; not only do they keep better in storage ...; but in their vegetable health they have attained a new standard. ... Howard ... spoke of the marked improvement in yield and quality of the vegetables, the better tilth and the increased earth-worm population The most striking feature was the general healthiness of the crops and the absence of insect and fungus pests. No chemical sprays have to be called into use. The plants themselves need no such doctoring."

A well-enriched soil resulted in excellent plant health, which, in turn, produced healthy animals that fed upon well-nourished plants; and human beings whose diet consisted of these fresh and wholesome healthy plants and animal products also enjoyed abundant health.

Organic foods are healthier

There is accumulating evidence from the scientific literature in support of people's experience for decades that organic foods are healthier than foods conventionally produced (see Box 20.1). Organic foods provide direct health benefits in having more health-promoting minerals, vitamins, and other natural compounds that protect against diseases, and also provide indirect benefits through the avoidance of toxic agrochemicals and additives that are frequently present in non-organic foods.

The British Society for Allergy, Environmental and Nutritional Medicine stated [12]: "We have long believed the micronutrient deficiencies common in our patients have their roots in the mineral-depletion of soils by intensive agriculture, and suspect that pesticide exposures are contributing to the alarming rise in allergies and other illnesses."

As long ago as the 1940s, a New Zealand boarding school began serving almost exclusively organically grown produce to its students, and reported after three years that [13] there were "lower incidences of catarrhal conditions, a 'very marked decline' in colds and influenza, more rapid convalescence, excellent health generally, fewer sports injuries, a greater resilience to fractures and sprains, clear and healthy skin, and improved dental health."

Box 20.1

Why organic foods are healthier

- Richer in essential minerals such as calcium, magnesium and iron, and trace minerals such as copper [5-7]
- Contain more vitamins and micronutrients [7]
- Rich in antioxidants and other compounds that fight cancer and heart disease (see main text)
- Low in nitrates [8, 9]
- Contain little or no harmful pesticide residues (see main text)
- Grown without polluting pesticides and fertilizers and hence provide a cleaner environment for health
- Contain little or no antibiotics that harm beneficial natural gut bacteria [10]
- Contain no harmful artificial food additives [11]

More recently, doctors and nutritionists administering "alternative" cancer therapies have found that a completely organic diet is essential for a successful outcome [11]. According to the Nutritional Cancer Therapy Trust (NCTT), nutritional cancer therapies that involve the avoidance of pollutants and toxins as much as possible, the exclusive consumption of organically grown foods and increases in nutrient intakes, have yielded good results [14]. The director of NCTT said that [15] "the overwhelming number of patients following alternative cancer therapies are those who have been declared terminal, with minimal life expectancies following initial allopathic treatment. The ability of these patients to gain remission from all clinical evidence of cancer is therefore very significant."

The United States Department of Agriculture reported some 30 years ago [16] that, "the highest death rate areas in the US generally corresponded to those where agriculturists had recognised that the soil was depleted." Degenerative diseases are prevalent in North America and Europe, in contrast with the absence of these diseases in places that have maintained natural farming methods.

Organic foods richer in minerals, vitamins and other nutrients

The mineral content in our food has become severely diminished. Fruits, vegetables and other plants that we rely upon to supply minerals in our diet cannot take adequate amounts of minerals from soil that is deficient in them. Conventional farming (i.e., intensive farming that uses chemicals) returns little or nothing to the soil and gradually depletes the soil of minerals. As only a small number of nutrients are replenished in chemical fertilisers (especially nitrogen, potassium and phosphorus), the soil gradually loses trace elements essential for health, such as boron, chromium and selenium.

In 1940, before chemical farming became widespread, and again in 1991, well into the agrochemical era, RA McCance and EM Widowson tested various fruits, vegetables (including carrots, broccoli, spinach and potatoes) and meats in Britain for mineral content [17]. They found that the amounts of calcium, magnesium, iron and copper in vegetables had declined during those 51 years by as much as 75 percent or even 96 percent, while meats had lost 41 percent of their calcium and 54 percent of their iron. Fruits had lost 27 percent of their zinc, and apples and oranges had lost 67 percent of their iron. The tests were repeated in 2002 with similar results. It is not only mineral content that has declined over the past half century. Levels of vitamins A and C have also dropped dramatically [18]. Wheat has lost much of its protein since 1900. Nitrogen fertilisation in conventional farming was found to decrease vitamin C concentrations in many fruits and vegetables [19]. On the other hand, fertilising crops with cow dung (as may occur on organic farms) can increase vitamin B12 to a level that could contribute significantly to the diet of vegans [20]. Secondary nutrients also tend to be more abundant in organically grown fruits and

vegetables [21].

UK's Food Standards Agency (FSA) has persistently declared that organic food is no more nourishing than conventional food. But the Soil Association pointed out in its own report [11] that, of the 99 studies on which the FSA based its opinion, only 29 studies were valid and relevant; and even those form a heterogeneous group and cannot be compared properly. The Soil Association review [11] found that on average, organic food has higher vitamin C, higher mineral levels and higher phytonutrients (plant compounds that can fight cancer) than conventional food.

Conventional produce also tends to contain more water than organic produce (on average 20 percent more). Thus, the higher cost of fresh organic produce is partly offset by getting a higher concentration of nutrients for the same weight.

A review published in 2001 of 41 studies and 1 240 comparisons [22] found statistically significant differences in the nutrient content of organic and conventional crops. Organic crops contained significantly more nutrients - vitamin C, iron, magnesium and phosphorus - and significantly less nitrates (a toxic compound) than conventional crops. Organic crops were of a better quality and had higher content of nutritionally significant minerals, with lower amounts of some heavy metals compared to conventional ones.

A study carried out by the Danish Institute of Agricultural Research found that organically reared cows produced milk on average 50 percent higher in Vitamin E (alpha tocopherol), 75 percent higher in beta carotene (precursor of Vitamin A) and two to three times higher in the antioxidants lutein and zeaxanthine than non-organic milk [23]. Organic milk also had higher levels of omega 3 essential fatty acids.

Organic crops contained significantly more nutrients - vitamin C, iron, magnesium and phosphorus - and significantly less nitrates than conventional crops

Organic fruits and vegetables richer in secondary metabolites that fight cancer and other diseases

Plant phenolics (flavonoids) are secondary metabolites (mainly pigments and flavour compounds or their by-products) that protect the plant against insect predation, bacterial and fungal infection, and photo-oxidation. These same plant phenolics are increasingly found to have many health benefits for people. Many flavonoids are effective in preventing heart disease, cancer and other degenerative diseases [24, 25].

The main target of these plant chemicals is to protect the cell against damage caused by active oxygen radicals. Oxygen radicals are generated from exposure to oxygen that has been activated by radiation, heavy metal ions and chemicals. Oxygen radicals cause cancer mainly by damaging DNA, resulting in mutations; they are also implicated in degenerative processes leading to cardiovascular disease and in age-related nerve cell damage [26].

Conventional agriculture depends on heavy applications of chemical fertilisers, frequent

spraying with chemical pesticides and irrigation. Such practices are believed to inhibit the production of flavonoids. On the contrary, organic agriculture, which eliminates the use of synthetic pesticides and chemical fertilizers, creates conditions favourable to the production of health-enhancing plant flavonoids, and many studies have found higher levels of flavonoids and other antioxidants in organically produced fruits and other crops.

For example, organic peaches and pears in Italy were significantly richer in total plant polyphenols than the conventionally grown counterparts [27]. Similarly plant phenolics were significantly elevated in organic and sustainably produced berries and corn compared to the conventional controls [28]. A ten-year study found two flavonoids - quercetin and kaempferol - on average respectively 79 and 97 percent higher in organically grown dried tomatoes than those conventionally grown [29].

The molecular mechanisms underlying the anti-cancer properties of natural dietary plant phenolics are complex [30]. The natural compounds had multiple functions. For example, they modulate signal-transduction cascades, and show both cytostatic (inhibiting cell growth) and cytotoxic (cell-killing) activities towards cancer cells. It has been suggested that combinations of plant chemicals would enhance cure rates of cancer with standard therapies [31].

Long-term oxidative stress contributes to nerve degradation and age-related diseases of the nervous system such as Parkinson's disease and Alzheimer's disease; and there is an emerging role for plant chemicals in combating age-related neurological dysfunction [32].

The benefits of organically grown foods have a lot to do with activating the plant's defence mechanisms to synthesize its own protective agents because synthetic pesticides are excluded. An active soil where plants and microbes interact also facilitates the exchange of metabolic compounds such as vitamins and cofactors. In addition, organically grown foods have a richer mineral content, on account of a more balanced nutrient uptake in the absence of artificial fertilizers

Organic strawberries with more Vitamin C and other antioxidants stop cancer cells more effectively

A study showed that organic strawberry extracts inhibited the proliferation of cancer cells more effectively than conventional strawberry extracts [33].

Bengt Lundegardh and Anna Martensson [34] at the University of Agricultural Sciences Uppsala Sweden believe that the benefits of organically grown foods have a lot to do with activating the plant's defence mechanisms to synthesize its own protective agents because synthetic pesticides are excluded. An active soil where plants and microbes interact also facilitates the exchange of metabolic compounds such as vitamins and cofactors. In addition, organically grown foods have a richer mineral content, on account of a

more balanced nutrient uptake in the absence of artificial fertilizers, which would have provided excesses of easily available nutrients such as nitrates.

Strawberries have been studied extensively for their cancer fighting ability. Researchers at Swedish University of Agricultural Sciences Alnarp and Lund University compared extracts of five organic and conventional cultivars for their ability to inhibit the proliferation of human colon and breast cancer cells. They found that extracts from organically grown strawberries inhibited cell proliferation more effectively than those conventionally grown, and in both types of cancer cells [33].

The strawberry extracts decreased cell proliferation in a dose-dependent manner between 0.025 to 0.5 percent dry weight of extract. At the highest concentration, the organic extracts inhibited proliferation of colon cancer (HT29) cells by 60 percent and breast cancer (MCF-7) cells by 53.1 percent; the corresponding values for conventional strawberry extracts were 49.7 percent and 37.9 percent respectively. The differences between conventional and organic were statistically highly significant.

The most effective extracts at inhibiting cell proliferation contained 48 percent more ascorbate and 5 times more dehydroascorbate. (Vitamin C is ascorbate plus dehydroascorbate, and is a water soluble anti-oxidant) The organic strawberries also had more total antioxidants and a higher ratio of ascorbate to dehydroascorbate.

Compost as a soil supplement increased the level of antioxidant compounds in strawberries [35]. The strawberry extracts, rich in vitamin C and other antioxidants, were found to interfere with the mitogen-activated protein kinase (MAPK) signalling cascade that leads to cell division, and hence to suppress cancer cell proliferation and transformation [36].

These findings on organic strawberries are in line with those on other organic fruits described earlier. Organic yellow plums were found to be richer in phenolic acids when grown in natural meadow or with a ground cover of clover than conventionally grown plums [37]. Plum and clover extracts induced apoptosis (cell death) and reduced the viability of human liver cancer cells [38].

Less nitrate

Nitrate levels in organic food are on average 15 percent lower [17], which may be important, as scientists at Glasgow University have found a link between nitrates in vegetables and gullet cancer, which has trebled within the UK over the past 20 years, claiming more than 3 000 lives a year [39]. The scientists believed that an increase in the use of nitrate fertilisers since World War II might be one of the main reasons for the rise in this cancer.

The main route for nitrate to reach our food chain is via contaminated drinking water (see Chapter 17), rather than through food. Hence, the health benefits of organic agriculture in the case of avoidance of nitrate come mainly through a cleaner environment.

No harmful food additives

More than 500 food additives are permitted as preservatives, colourings, and flavouring in the UK [40] where the Soil Association, which certifies most of the organic produce in the country, allows only 30 of the 35 in the EU Regulation on organic food. The additives banned from organic foods include those with proven health risks such as artificial sweeteners and colours. Those permitted in organic foods, such as citric acid, are generally derived from natural sources, and all food colourings are banned, whether natural or not, except annatto, which is legally required in Double Gloucester and Red Leicester cheese. All genetically modified (GM) ingredients are banned, even as additives.

Food additives have been linked health problems as diverse as heart disease, hyperactivity, cancers, asthma, osteoporosis and migraines [41].

But official regulatory bodies have denied or ignored these links.

A recent case involves food colourings found in many soft drinks [42]. The prevalence of ADHD has greatly increased over the past fifty years, and it has been widely suspected that some artificial food colourings are to blame. As long ago as 1975, physician Ben Feingold pointed to the increase in ADHD, which he called hyperkinesis and learning disabilities, and suggested it was correlated with the growth in consumption of soft drinks and synthetic flavours since World War II [43]. Since then, researchers have indeed found such an association.

UK's Food Standards Agency (FSA) commissioned a team at Southampton University to conduct further investigation on mixtures of red and yellow food colourings mixed in with the preservative sodium benzoate. The results were unequivocal and replicated earlier findings. The researchers said that their results [44], "lend strong support for the case that food additives exacerbate hyperactive behaviour". Moreover, they added that, "adverse effects are not just seen in children with extreme hyperactivity (ie ADHD), but can be seen in the general population and across the range of severities of hyperactivity."

Still, the FSA has refused to ban these colourings and is leaving parents to find out the offending E numbers for themselves. The mixtures used in the Southampton study were Mix A: Sunset yellow (E110), Tartrazine (E102), Carmoisine (E122), and Ponceau 4R (E124); Mix B, Sunset yellow (E110), Quinoline yellow (E104), Carmoisine (E122), Allura red (E129). Both mixtures affected the children.

Avoiding pesticides

Conventional agriculture may use any of the 447 pesticides permitted (see Chapter 18), while regulators set legal limits of the pesticides and residues in food as protection for the public. However, research carried out by the Soil Association showed that many popular foods contain levels of pesticide residues well over the legal limit, as shown by tests done by the Government's own Pesticide Residue Committee. Based on these findings, the Soil Association has

calculated that in 2003 [45],

- More than 32 000 tonnes of potatoes containing residues of Aldicarb over the legal limit may have been eaten. Aldicarb acts like a nerve poison, and is classified by the World Health Organisation as 'extremely hazardous'. Some 33 million apples consumed may have had residues of Chlorpyrifos over the legal limit. (Chlorpyrifos is an organophosphate, very toxic to animals and humans.)
- Over 1.5 million punnets of raspberries destined for consumers had residues of Chlothalonil over the legal limit. Chlorothalonil is classified as a possible carcinogen by the US Environment Protection Agency (EPA).
- Over 170 million pears sold in the UK could have residues of Carbendazim, a possible carcinogen according to the US EPA.

Such contamination is not unusual, and could be worse in isolated cases. In 2004, the UK Government's Pesticide Residues Committee (PRC) tested 167 samples of fruit and vegetables supplied to schools as part of the Government's Schools Fruit and Vegetable Scheme (SFCS). A staggering 84 percent of the samples contained pesticides, with multiple pesticides detected in 65 percent of the sample [46]. These figures are far higher than the pesticides found in samples of fruit not destined for the school fruit scheme. In the same year, the PRC also tested 55 samples of organic fruit, vegetables and bread on sale in shops and found that they were almost completely (96 percent) free of pesticides. But organic fruits and vegetables are not part of the UK Government's SFVS.

A comprehensive Soil Association review of scientific research in 2001 has already shown that,

In 2004, the UK Government's Pesticide Residues Committee tested 167 samples of fruit and vegetables supplied to schools as part of the Government's Schools Fruit and Vegetable Scheme (SFCS). A staggering 84 percent of the samples contained pesticides, with multiple pesticides detected in 65 percent of the sample



Organic garden Mindanao

on average, organic food is better for us than non-organic food [11].

Most pesticides are acutely toxic to humans at sufficiently high concentrations. It is estimated that pesticides poisonings are responsible for about one out of every sixteen calls to poison control centres in the United States [47]. Chronic health effects from pesticides include neurological effects, disruption of the endocrine system, immune suppression, reproductive functions, infant development, and cancer [11, 48]. .

Scientists in the Technical University of Munich Germany found that 10 percent of the hormone passed right through the animals into the faeces, and during storage of the manure, both drugs resisted bacterial breakdown, and had a half-life of 260 days

The National Research Council in the United States concluded in their 1993 report [49] that dietary intake is the major source of pesticide exposure for infants and children in the United States, and this exposure may account for increased pesticide related health risks in children compared to adults (see Box 20.2).

Researchers at the Rollins School of Public Health, Emory University, Atlanta, and Department of Environmental and Occupational Health Sciences, University of Washington, Seattle, in the United States measured dietary exposure in the urine of infants and children before and after they switched from consuming conventional to organic produce and then again back to conventional. They showed that the metabolites of the organophosphates malathion and chlorpyrifos declined to undetectable levels immediately after switching to organic diets, and remained undetectable until they switched back to conventional diets [52]. This supported the conclusion from their earlier work that the children were mostly likely exposed to organophosphate pesticides exclusively through their diets.

Children are not the only ones affected by pesticides. In Denmark, a study on human sperm and semen quality in relation to organic or conventional diet found that the group consuming mainly organic food had a reduced pesticide intake based on the pesticide levels measured in their food. The researchers concluded that pesticide exposure in the diet did not entail a risk of impaired semen quality [53] even though the group of men not consuming organic food had a

significantly lower proportion of morphologically normal sperm. The proportion of morphologically normal sperm is generally considered predictive of pregnancy outcome, as abnormal sperms are indicative of DNA damage [54, 55]. It is not clear why the investigators thought that increase in abnormal sperms did not impair semen quality.

The serious health impacts of pesticides used in cotton crops on farm workers and the public are dealt with in Chapter 21.

Avoiding hormones and antibiotics

Organic foods also avoid antibiotics as well as hormones added to promote milk or meat yield in non-organic production, especially in the United States.

In the US, two-thirds of some 36 million beef cattle are fattened up using hormones. Many cattle are fed muscle-building androgens, usually testosterone surrogates that some athletes use to enhance performance. Other animals are fed estrogens or progestins that shut down the oestrus cycle, so as to build more meat. While federal law forbids self-medication with most steroids, these drugs are permissible and widely used in the US cattle industry [56]. Concerns have focussed on trace residues of these hormones in the meat. But a more important route of exposure is via contaminated drinking water, as a substantial portion of these powerful agents is excreted directly by the animals. It has been known since the 1970s that the synthetic hormone diethylstilbestrol (DES), fed to chickens and cattle to castrate male animals, fostered the development of cancer in daughter of women who were given the hormone to avoid miscarriages. The animals' excretions were releasing even then something like 13 tons of DES a year into the environment. Although the Food and Drug Administration outlawed the veterinary use of DES by the mid-1970s, the provision of other hormones continued. These hormones are 100 to 1 000 times stronger in biological activity than the most potent of the industrial endocrine disrupters, according to Bernard Jegou, director of research at INSERM (French Institute of Health and Medical Research) in Rennes. Indeed, evidence has been emerging that fish downstream from cattle farms have been adversely affected by the increase in hormone concentrations in the water. The effect on other wild life is completely unknown.

Box 20.2

What the US EPA says about pesticides in infants

The US Environmental Protection Agency states [50]: "Laboratory studies show that pesticides can cause health problems, such as birth defects, nerve damage, cancer, and other effects that might occur over a long period of time. However these effects depend on how toxic the pesticide is and how much of it is consumed. Some pesticides also pose unique health risks to children."

That is because [51], "their internal organs are still developing and maturing", and "in relation to their body weight, infants and children eat and drink more than adults, possibly increasing their exposure to pesticides in food and water." Furthermore, "certain behaviors - such as playing on floors or lawns or putting objects in their mouths - increase a child's exposure to pesticides used in homes and yards."

Pesticides may harm the developing child by blocking the absorption of important food nutrients necessary for healthy growth. Furthermore, if the child's excretory system is not fully developed, the body may not fully remove pesticides. There may also be crucial periods in human development when exposure to toxin can permanently change the way an individual's system works.

Scientists in the Technical University of Munich Germany found that 10 percent of the hormone passed right through the animals into the faeces, and during storage of the manure, both drugs resisted bacterial breakdown, and had a half-life of 260 days.

Since 1988, the EU has banned imports of meat of hormone-treated animals. The US and Canada, which produce such meat, have vigorously fought the ban at the World Trade Organization. But although the ban is still in place, there appears to be illicit use of hormones in Europe.

In the United States, dairy cows may also be injected with a genetically modified growth hormone (rBGH also known as rBST, recombinant bovine somatotropin) to increase milk production. Both the Canadian and European governments have refused to permit the use of this hormone. Not only does it increase the incidence of mastitis in cows, but it is also linked to cancer in human beings [57].

Antibiotics are not used routinely in organic farms as they are in conventional farms [58]; nor are they often needed. Better feed and living conditions maintain animals in good health. When disease does strike, alternative measures such as homeopathy are preferred. The routine use of antibiotics in conventional livestock is for non-therapeutic purposes. Antibiotics promote slightly faster growth and prevent diseases that would otherwise result from raising animals under stressful, overcrowded and unsanitary conditions typical of non-organic industry farms. It is estimated that 70 percent of all antibiotics used in the United States are fed to farm animals [58]. The overuse of antibiotics in agriculture has almost certainly contributed to the growing antibiotic resistance of serious pathogens in hospitals.

Less mycotoxins

There has been a propaganda campaign from the proponents of genetically modified (GM) crops against organic food. One claim is that organic produce has increased levels of mycotoxins, toxic metabolites produced by fungi found in infected grains and nuts. The best known mycotoxin is aflatoxin, which linked to liver cancer.

This claim has been thoroughly debunked [59].

Peer-reviewed publications indicate that organic foods are not more hazardous sources of mycotoxins than conventional foods. On the contrary, organic foods tend to be less contaminated, and may also provide protection from the toxins. Furthermore the use of GM maize has not provided major protection from mycotoxins in comparison to conventional maize.

As far as aflatoxin is concerned, biological control using fungi unable to make the toxin to control those that produce it, has proved effective in cotton; and conventional breeding to produce strains resistant to fungal infestation has been successful in maize.

No genetically modified organisms (GMOs) that may be inherently unsafe for consumption

Organic standards forbid certification as organic of any food that has been genetically modified. This restriction, unfortunately, was changed for the European Union, as the EU Agricultural Ministers have decided to allow contamination of 0.9 percent, as in conventional food [60]. But current organic standards in the UK still prohibit any GM content in organic food. Transfer of genetic material from one species to another does not generally occur in nature. Forcible transfer of genes in a laboratory, i.e., genetic engineering or genetic modification, entails many hazards to the natural genetic material of the recipient. The implantation of a foreign gene into the genome of the recipient is random; yet it is now known that the position of a gene is important in determining what effects it will produce.

The old belief, which remains the basis of GM technology, was that there is a one-to-one correspondence between genes and traits. This belief has been disproved, especially since the sequencing of the human genome [61]; yet the GM developers have still failed to take heed.

Dr. Irina Ermakova from the Russian Academy of Sciences has found that female rats fed genetically modified soya gave birth to abnormal litters with excessive stunting and deaths, while the remaining offspring are sterile

GM developers continue to assure the public that their products are safe. But there has been a string of reports indicating that quite the opposite is the case. In India, thousands of sheep died after grazing on post-harvest GM cotton fields [62], and hundreds of farmers and cotton handlers suffered allergic reactions [63]. In Australia, mice given a diet containing peas that had been modified with a gene from a common bean developed debilitating immune reactions to the transgenic protein, and the decade-long project of developing the transgenic peas had to be abandoned [64]. And Dr. Irina Ermakova from the Russian Academy of Sciences has found that female rats fed genetically modified soya gave birth to abnormal litters with excessive stunting and deaths, while the remaining offspring are sterile [65]. It is becoming increasingly clear that GM food and feed may be inherently unsafe [66].

- 21 -

Picking Cotton Carefully

Cotton is known as "white gold" in some parts of the world, but the price in pesticide poisonings and the decimation of ecosystems is too high to pay; a shift to organic cotton farming should be made mandatory



Organic cotton farmer in Benin sprays food to attract beneficial insects for pest control

Fashion leader backs organic cotton

Designer Katherine Hamnett did something very different at London Fashion Week in 2007. Instead of showcasing her latest ready to wear clothes she featured a report and a film by the Environmental Justice Foundation (EJF) in collaboration with the Pesticides Action Network (PAN), exposing the human health and environmental cost of pesticide use in global cotton production.

Hamnett is famous for inspiring a popular fashion campaign for bold, life-affirming slogans printed onto cotton t-shirts during the 1980s. Almost twenty five years later, her collections are still highly prestigious. But now, she is doing

everything in her power to support organic cotton farmers, and produces her unique t-shirts only on certified organic cotton, and her latest slogan "Save the Future" is a testament to her values.

At the Museum of Natural History, which hosted this year's event, I asked her how she felt about GM cotton. "I'm terrified of it," she said. "Bt cotton is of no benefit to farmers and has been a massive failure. Monsanto should be broken up! They have taken GM cotton to the scale of genocide in countries like India, and created devastation on all levels."

ISIS shares her concerns about Bt toxins in GM crops [1]. We have also thoroughly documented the failures of GM cotton worldwide

[2]. The EJF and PAN joint report *The Deadly Cost of Chemicals in Cotton* [3] is another damning indictment of the agrochemical industry. The use of forced child labour in the cotton fields of Uzbekistan (see later) is a wake-up call to the fashion industry and consumers to demand organic and fairtrade cotton across the board.

Conventional cotton awash with hazardous chemicals

For over 5 000 years, global cotton production has occurred without the aid of hazardous agrochemicals. Cotton was planted at low densities and rotated with other crops to ensure the optimum health of the soil. Pest cycles were taken into consideration before planting and harvesting. Things changed after World War II with the advent of neurotoxins such as DDT that were considered to be a cheaper way of controlling pests than strategic crop management and agricultural labourers. The recent new wave of GM cotton represents 30 percent of the global cotton and estimated to reach 50 percent by 2010. According to PAN, only 0.15 percent of the world's cotton is guaranteed to be free of pesticide, and organic.

In fact, conventional and GM cotton accounts for 16 percent of global chemical pesticide use, more than any other single crop, and reaps US\$2 billion for the chemical industry every year. Of that, US\$112 million is spent on Aldicarb, an acutely toxic pesticide classified by the World Health Organisation as "WHO1a", or "extremely hazardous." One drop is sufficient to kill an adult male. Yet one million kilos of Aldicarb was applied to cotton crops in the USA in 2003. The WHO reports three million pesticide poisoning per year and 20 000 unintentional deaths, and at least 1 million agricultural workers around the world are hospitalised because of acute pesticide poisoning each year [4].

Food chains and water supplies polluted by chemicals

Conventional cotton is noted as the biggest and most important "non-food" agricultural crop in the world yielding 21.8 million tonnes per year. But some 34 million tonnes of high protein cottonseed is also produced for food and feed annually. Around 24 million tonnes of whole cottonseed, cottonseed husks and meal is used in animal feed, and can make up a quarter of a dairy herds total nutrition. A further 3.1 million tonnes of cottonseed oil is used for cooking by 8 percent of the world population. In some areas as much of 65 percent of the cotton harvest can enter the food chain. Both the FAO and WHO recognise that the chemical pesticides applied to cotton can contaminate cottonseed and its derivatives. While several other studies have shown that cottonseed is a "significant pathway by which hazardous pesticides applied to cotton may enter the human food chain." Therefore, Monsanto has deliberately misled regulators by stating that Bt cotton is not used for food.

Conventional and GM cotton is grown mainly in

China, USA, India, Pakistan, Uzbekistan, Brazil, Australia, Greece and West Africa. Numerous studies have recorded detectable levels of Lindane and Endosulfan, (both organochlorines known for adverse health and environmental impacts) in local water resources in these areas. In India, over 3 000 tonnes of Endosulfan is applied to cotton crops annually. According to one farmer, who observed birds and frogs dying after eating insects that were sprayed with Endosulfan, he said, "Fields smell awful two or three days after spraying because virtually every living thing has been killed and starts to rot". [3]. It is hoped that recent action by the European Commission to list Endosulfan under the Stockholm Convention on Persistent Organic Pollutants will eradicate it's use from global agriculture.

Conventional and GM cotton account for 16 percent of global chemical pesticide use, more than any other single crop, and reaps US\$2 billion for the chemical industry every year

In Brazil, water samples taken from streams, rivers and surface water in the Mato Grosso cotton State, showed that 80 percent were contaminated by Endosulfan. In Ghana's Lake Volta Lindane was present in 22.7 percent of samples and Endosulfan present in 18 percent. In the US, an organophosphate called Dicrotophos used extensively in cotton growing was detected in some 35 percent of samples.

Children and workers at risk from pesticides

The worst affected by pesticides are the developing countries, where 99 percent of cotton production takes place. According to Dr Vyvyan Howard, a leading UK toxicologist [5] there is a chronic lack of protective apparatus, poor labelling of pesticides, and inadequate safeguards to protect farm workers and their families in developing countries. Human casualties are unsurprising as pesticides are neurotoxins designed to inhibit the growth of organisms by impairing the biological processes necessary to life. Symptoms of acute pesticide poisoning include vomiting, skin rashes, headaches, tremors, respiratory problems, muscle cramps, blurred vision, loss of co-ordination, seizures and death.

India has 8.3 million hectares under cotton, the largest area in the world [3]. Despite using only 5 percent of land area, cotton accounts for 55 percent of the annual total of US\$355 million spent on pesticides. A staggering US\$255 million is spent just on controlling the bollworm cotton pest every year. Children of farm workers are particularly vulnerable to agrochemical exposure as they play or help in the fields. A 2003 study in India compared 899 children living in cotton regions with those where few agricultural pesticides were in use. The results showed that children living in cotton producing areas performed significantly worse in tests assessing mental ability, cognitive skills, concentration, balance and co-ordination. A 2005 study in three different villages all farming cotton recorded 323 separate

instances of ill health over a five months period, 83.6 percent of which were associated with pesticide poisoning. A case study of one farmer's return to organic practices in India demonstrates how to avoid the health risks, ecological damage and debt resulting from conventional cotton farming. (see Chapter 14)

Cotton workers are often so poor they are forced to store pesticides within their homes, improvise with their own utensils to apply chemicals to cotton and to re-use the empty pesticide canisters as water vessels. A tragic tale is the death of four children whose dad left his pesticide soaked clothes on the roof after a day's work. During the night it rained and the pesticides dripped through the roof onto the breakfast bowls in the kitchen below, which the children ate from in the morning.

West African farmers forced into dependence on lethal pesticides

Over ten million people are dependent on conventional cotton grown in French speaking Benin and Mali [6]. There the resourceful farmers produce cotton crops by relying entirely on rainwater. However, they are dependent on privatised cotton companies that control the infrastructure of seeds, fertilisers and pesticides supplied to them on credit. But because the farmers are also dependant for collection of their unsubsidised cotton harvest they must adhere to a pesticides spraying regime of at least 6-10 chemical sprays per crop per season. When health problems from pesticides require medical attention,

farmers that can afford it spend what little money they make on treatment.

By 1999, the cotton pests had become resistant to the most commonly used poisons, so a research company attached to the French Government recommended that Endosulfan be used for the first two sprays of each season. Shortly after that, the authorities reported the deaths of 37 people within farming communities and a further 36 with serious health problems. These complaints were followed up by an NGO, the Organization Beninoise pour la Promotion de l'Agriculture Biologique, which confirmed 24 fatalities and estimated a further 70 deaths in cotton areas. The independent investigations continued for a further two spraying seasons; 577 chemical poisonings and 97 deaths were recorded during 2000-2003, of which 69 percent were attributable to Endosulfan.

Organic cotton better for farmers than GM cotton

There is hope for African cotton farmers determined to grow organic cotton, as many African countries are fighting to remain GM-free under intense pressure [7]. Mali is producing 1 500 tonnes of organic cotton a year, much of which UK retail giant Marks and Spencer is buying under fair trade practices and demand outstrips supply. However, the difficulty with mainstreaming organic cotton production in Mali is that where soil fertility has declined under intensive conventional cotton farming the methods to improve soil health such as composting, green manure, and cattle dung



Women spinning organic cotton in Senegal

requires land that is already under crop.

Monsanto has pushed aggressively into neighbouring Burkino Faso where trials of Bt cotton are underway [6]. If GM cotton gets a foothold in West Africa it will be harder to establish an effective organic production system. To that end, a citizen's jury of farmers met to consider the effects of growing GM cotton with representatives of government, NGOs, researchers, and other farmers who have been growing Bt cotton in South Africa. The jury unanimously voted to ban GM cotton in favour of improving traditional varieties, low input agriculture and local seed varieties. The benefits for organic cotton farmers were perceived as lower costs, higher prices for harvests and reduced health problems. (see Chapters 22 for the manifold benefits of organic farming for rural communities in Africa and India.

Uzbekistan – State enforced cotton slavery

In Uzbekistan the use of chemicals in cotton production has gone overboard [8]. It is estimated that between 20kg and 90kg of pesticide is applied per hectare of cotton, which is almost 20 times the average that is used on US cotton. The excessive use of pesticides has contaminated up to 90 percent of land and groundwater at 100-150metres with DDT, lindane, and other chemicals. The Uzbekistan State forces children, teachers and doctors away from their desks for months at a time throughout the year to spray pesticides and harvest cotton in the fields. Schools are closed for compulsory cotton picking and children are often beaten and underpaid for their efforts [9]. (Since our report Uzbekistan child labour has been the subject of a major investigation by BBC2 Newsnight.) Studies on children in rural areas reveal a litany of diseases linked to environmental health problems and toxicology such as immune deficiencies, chronic renal and lung disease, developmental retardation, and hypothyroidism. Downstream of cotton plantations, a NATO study recorded DNA mutations that are 3.5 higher than normal, rendering populations vulnerable to cancers.

The Aral Sea, once an oasis in the deserts of Central Asia, has been extensively drained of water for cotton production in Uzbekistan, which has decimated ecosystems and traditional livelihoods. Native fish have all but disappeared, and the Aral fishing fleet, which once supplied the largest fish processing plant in Russia lies stranded on the dried up sea bed. According to Medecins Sans Frontiers, an estimated 43 million tonnes of pesticide-laden dust is blown throughout Central Asia every year from the former seabed and contaminated soils [10]. The region suffers the highest incidence of throat cancers in the world.

Organic cotton – fair trade an issue

Organic cotton farming is based on a system that maintains and regenerates soil fertility without the persistent use of chemicals, toxins, pesticides, fertilizers or GM seeds or sprays. The good news is that organic cotton production for the 2006/2007 crop year has increased by 49 percent (see Fig.

21.1), with 265 517 bales produced in 24 countries on all arable continents [11]. The top organic cotton producing countries are Turkey, India, China, Syria, Peru, The USA, Uganda, Tanzania, Israel and Pakistan.

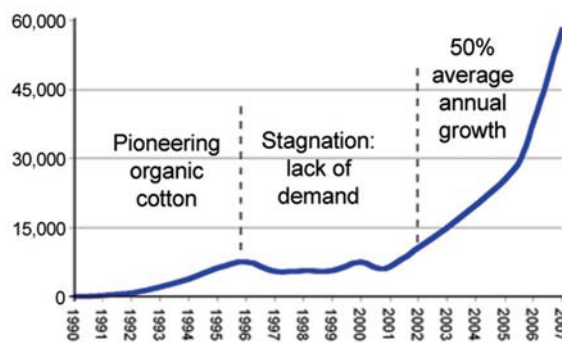


Figure 21.1 World organic cotton production

According to the Organic Exchange Organic Cotton Market Report 2007 [12] global retail sales increased 85 percent to US\$1.1billion in 2006, (up from US\$583million in 2005) and is projected to increase by 83 percent to US\$1.9 billion by the end of 2007. The Organic Exchange predicts that by 2008 the organic cotton market will be worth US\$3.5 billion and almost double that by 2010. Global corporations such as Wal-Mart (USA) and Nike (USA), Co-Op (Switzerland) are expected to have been the biggest users of organic cotton in 2007 (see Fig. 21.1). Campaigners warn that entering the mass market could be the toughest challenge for organic cotton producers yet. The major concern is that the corporations continue the ethical and equitable trading practices set up by organic cotton pioneers such as Katherine Hamnett.

There has been a huge surge in consumer demand for organic products in recent years that has kick-started a slump in organic cotton fibre production. The demand for clothes, home textiles and personal items made from organic fibres such as cotton, wool and linen has prompted fashion companies to expand existing organic cotton programs. People Tree (UK) and Edun (Ireland) have been running organic cotton community fair trade programmes in India, Africa, and Central and South America for several years. The entry into the organic market in 2007 by major brands such as Stella McCartney, H&M (Sweden), Levi-Strauss & Co (USA) and Woolworth (SA) and Next (UK) will further boost expansion.

Choosing the right cotton

The reports by the EIJ and PAN underline the urgency of changing the ways in which conventional cotton is farmed and purchased. I asked Katherine Hamnett what else could be done. "I would like to see a ban on cotton from Uzbekistan, cotton should be organic, and the cotton subsidies in USA, EU, and China should be stopped," she said, "It's not about choosing something else, it's about choosing the right cotton."

Socioeconomic Benefits

- 22 -

Socially Sustainable & Profitable Production

Evidence shows that production for local and national markets that puts farmers first increases productivity and food security, reduces poverty and hunger, and results in preserving rural life and economies while benefiting health and the environment



Peri-urban agriculture in Burkina Faso

Social welfare an integral part of sustainable food production

There is a convergence of views expressed in earlier chapters (Chapter 3, 4, 5, 8, 10, 11, 12, 14, 17) towards the defining features of sustainable food production, which are embodied in the notion of "food sovereignty" (see Chapter 2). Inherent to food sovereignty is the principle that production for local and national markets is more important than production for export; and that poverty and hunger, the preservation of rural life, economies and environments must all be addressed, while adopting agro-ecological practices to managing and regenerating natural resources. The notion of "sovereignty" also

includes the principle that food production is farmer-led and dependent on local knowledge and skills as well as indigenous crop and livestock biodiversity. And it goes without saying that sustainable food production must also contribute to public goods such clean water, wildlife, carbon sequestration in soils, flood protection and landscape quality, as well as health-promoting nutritious food for all (see Chapters 18, 19, 20 and 21).

We shall review how these defining features have guided the practice of sustainable food production and fulfilled the aims and aspirations of farmers and consumers.

Overall sustainability in organic production

A study was carried out to investigate the sustainability of organic, conventional and integrated (combining both organic and conventional methods) apple production systems in Washington from 1994-1999 [1, 2]. The organic system ranked first in terms of environmental and economic sustainability, the integrated system second and the conventional system last. The indicators used were soil quality, horticultural performance, orchard profitability, environmental quality and energy efficiency.

Soil quality ratings in 1998 and 1999 for the organic and integrated systems were significantly higher than for the conventional system, due to the addition of compost and mulch. All three systems gave comparable yields, with no observable differences in physiological disorders or pest and disease damage. There were satisfactory levels of nutrients for all systems. A consumer taste test found organic apples less tart at harvest and sweeter than conventional apples after six months of storage.

Organic apples were the most profitable due to price premiums and quicker investment return. Despite initial lower receipts in the first three years the time required to convert to certified organic farming, the price premium in the next three years averaged 50 percent above conventional prices. In the long term, the organic system recovered costs faster. The study projected that the organic system would break even after 9 years, the conventional system after 15 years, and the integrated system after 17 years.

Environmental impact was assessed by a rating index to determine potential adverse impacts of pesticides and fruit thinners: the higher the rating, the greater the negative impact. The rating of the conventional system was 6.2 times that of the organic system. Despite higher labour needs, the organic system expended less energy on fertiliser, weed control and biological pest control, making it the most energy efficient.

A second study evaluated the financial and environmental aspects of sustainability of organic, integrated and conventional farming systems by applying an integrated economic-environmental accounting framework to three farms in Tuscany, Italy [3]. In terms of financial performance, the gross margins of steady-state organic farming systems were higher than the corresponding conventional farming systems' gross margins. The organic systems performed better than the integrated and conventional systems with respect to nitrogen losses, pesticide risk, herbaceous plant biodiversity and most other environmental indicators. The results provided evidence that organic farming potentially improves the efficiency of many environmental as well as remunerative indicators.

Efficient profitable production

The evidence is now clear that lower yields are by no means inherent to organic agriculture, quite the contrary is the case, yields from organic agriculture are comparable or higher than those

from conventional agriculture (see Chapters 9, 13, and 15), especially for smaller farms (see Chapters 11, 12, 16 and 17).

Comprehensive data dating back to 1999 already showed that smaller farms produce far more per unit area than larger farms (which tend to be monocultures characteristic of conventional farming) [4]. Though the yield per unit area of one crop may be lower on a small farm than on a large monoculture farm, the total output per unit area, often composed of more than a dozen crops and various animal products, can be far higher. Small farms are also more efficient than large ones in terms of land use and 'total factor productivity', an averaging of the efficiency of use of all the different factors that go into production, including land, labour, fertiliser and other inputs, capital, etc.

Studies in Bolivia showed that though yields were greater in chemically fertilised and machinery-prepared potato fields, energy costs were higher and net economic benefits lower, than where native legumes have been used as rotational crops [5]. Surveys indicate that farmers prefer the latter system because it optimises the use of scarce resources, of labour and available capital, and is accessible to even poor producers.

Two trials in Minnesota evaluated a two-year corn-soybean rotation and a four-year corn-soybean-oat/alfalfa-alfalfa crop rotation under four management strategies: zero, low, high and organic inputs [6]. Averaged across a seven-year time frame from 1993-1999, corn and soybean yields in the four-year organic strategy were 91 and 93 percent, and 81 and 84 percent, respectively, of the two-year high input strategy. However, oat yields were similar for the four-year organic or high input strategies, and alfalfa yields in the four-year organic strategy were 92 percent that of the four-year high input strategy in one trial, and in the second trial, the yields were the same. Despite the small reductions in corn and soybean yields, the organic strategy had lower production costs than the high input strategy. Consequently, net returns were equivalent, even without considering organic price premiums.

A comprehensive review of the many studies comparing grain and soybean production conducted by six US Midwestern universities since 1978 found that organic production was equivalent to, and in many cases better than, conventional [7]. Organic systems had higher yields than conventional systems that featured continuous crop production (i.e. no crop rotations), and equal or lower yields than conventional systems that included crop rotations. In drier climates, organic systems had higher yields, as they were more drought-hardy than conventional systems (see also Chapter 13). The organic cropping systems were always more profitable than the most common conventional systems if organic price premiums were factored in. When the higher premiums were not factored in, the organic systems were still more productive and profitable in half the studies. This was attributed to lower production costs and the ability of organic systems to out-perform the conventional in drier areas, or during drier periods. The author concluded,

"organic production systems are competitive with the most common conventional production systems", and suggested that, "if farmers obtain current market premiums for organic grains and soybeans, their organic production generally delivers higher profits than non-organic grain and soybean production" (p.2).

The 15-year results from the Rodale Institute showed that after a transition period with lower yields, the organic systems were competitive financially with the conventional system [8]. While the costs of the transition are likely to affect a farm's overall financial picture for some years, projected profits ranged from slightly below to substantially above those of the conventional system, even though economic analyses did not assume any organic price premium. The higher profits for the organic farms came largely from higher corn yields, which nearly doubled after the transition period. When prices or yields were low, organic farms suffered less than the conventional and had fewer income fluctuations, as they had a diversity of crops other than corn to sell. Expenses on the organic farms were significantly lower than on the conventional - the latter spent 95 percent more on fertilisers and pesticides. Overall production costs on the organic farms were 26 percent lower.

Increased local food production for local consumption is the key to sustainability

Despite adequate global food production, many still go hungry because increased food supply does not automatically mean increased food security. It depends on who produces the food and has access to the technology and knowledge to produce it, and who has enough money to buy the food [9]. Poor farmers cannot afford expensive technological package of the "Green Revolution" that raise yields when given high inputs in fertilizers and water, which have largely displaced the traditional knowledge and technologies that have sustained the farmers for thousands of years before (see Chapter 2).

Many farmers show 'lagging productivity', not because they lack 'miracle' genetically modified seeds that contain their own insecticide or tolerate massive doses of herbicide, but because they have been displaced onto marginal, rain-fed lands by the Green Revolution, and face structures and macroeconomic policies of the World Bank, the IMF and the WTO that have built on historical inequalities, and that are increasingly inimical to food production by small farmers [10]. As such, their agriculture is best characterised as 'complex, diverse and risk prone' [11], and they have tailored agricultural technologies to their variable but unique circumstances, in terms of local climate, topography, soils, biodiversity, cropping systems, resources, etc. It is these farmers, already risk-prone, who stand to be harmed most by the risks of GM crops [10].

As mentioned in Chapter 8, most of the world's food is grown, collected and harvested by small farmers, pastoralists and fisherfolk for local

consumption. There are 1.35 billion farmers in the world today (see Table 22.1) [12], constituting more than half of the world's 2.6 billion active population. The vast majority, 1.29 billion are in the South, 270 million in India alone. Most of them practise small-scale farming by hand or with animals, only a very few (20 m) relying on modern machinery such as tractors. As Michel Pimbert, Programme Director of the International Institute for Environment and Development, points out, "local food systems are the foundation of people's nutrition, incomes, economies and culture [13].

Sustainable agricultural approaches must therefore allow farmers to improve local food production with low-cost, readily available technologies and inputs, without causing environmental damage. This was indeed found to be the case in a comprehensive review of the evidence published in 2001 [9]. Most sustainable agriculture projects and initiatives reported significant increases in household food production - some as yield improvements, others as increases in cropping intensity or diversity of produce.

The evidence showed that:

- Average food production per household increased by 1.71 tonnes per year (up 73 percent) for 4.42 million farmers on 3.58 million hectares.
- Increase in food production was 17 tonnes per

	Total population	Active population	Active farming population
World population	6.1	2.5	1.350
North	1.2	0.4	0.045 (11% of North Total)
South India	4.9	2.2	1.20 (59% of South Total) 0.27 (20% of world total)

Table 22.1. Numbers of farmers in the world (billion)



Local foods Lusaka, Zambia

year (an increase of 150 percent) for 146 000 farmers on 542 000 hectares cultivating roots (potato, sweet potato and cassava).

- Total production increased by 150 tonnes per household (an increase of 46 percent) for the larger farms in Latin America (average size 90 hectares).

The review found that as food supply increased, domestic consumption also increased, with direct health benefits, particularly for women and children. Furthermore, 88 percent of the 208 projects made better use of locally available natural resources, and 92 percent improved human capital through learning programmes. In more than half the projects, people worked together, often self-organizing into local associations and networks.

Local food systems depend on many different local organizations to coordinate food production, storage and distribution, and people's access to food [13]. They play crucial roles in meeting many of the Millennium Development Goals adopted by United Nations Member States in 2000 to reducing poverty and providing food security through sustaining diverse food systems, livelihoods and habitats, and in producing and spreading knowledge and innovation. Yet these organisations and local food systems are largely ignored or even undermined by the international development community.

An example of such a local organization is ANDES, which supported indigenous Queshush communities in the Cusco region of the Peruvian Andes to establish local platforms for the adaptive management of mountain landscapes and livelihood assets. In 2000, the indigenous communities celebrated the opening of the Potato Park as a Community Conserved Area (CCA) to

Non-certified organic agriculture, practiced by millions of indigenous people, peasants and small family farms makes a significant contribution to regional food security. In Latin America they account for more than 50 percent of the maize, beans, manioc and potatoes produced; in Africa, most of the cereals, roots and tubers; in Asia, most of the rice

protect the natural landscape as well as the cultural systems that created the landscape. A great part of biodiversity in the CCA are domesticated, the products of centuries of deliberate ecosystem management, genetic selection and breeding by the Andean farmers. The majority of the indigenous peoples in the area continue to farm traditional crop varieties and animal breeds, and many of their small plots contain more than 100 different potato varieties.

Putting farmers first

Sustainable agricultural approaches recognise the value of traditional and indigenous knowledge, and of farmers' experience and innovation. The importance and value of learning from farmers, and of farmer-led participatory agricultural research, are well established in concepts such as 'farmer first' [11, 14]. And farmers are also the source of the most important innovations. Case studies and experiences of successful agro-ecological innovations from Africa, Latin America and Asia [15] provide evidence that low-external-input agriculture using agro-ecological practices could make an important contribution to feeding the world over the next 30 to 50 years. Relying on mainly local resources and knowledge, farmers are able to increase yields substantially, sometimes doubling or tripling outputs. To cite one example, in Mali's Sahelian Zone, soil and water conservation practices and agro-forestry have increased cereal yields, in some cases from 300 kg/ha to 1 700 kg/ha, about twice the level needed to meet basic food needs. Emphasis has also been placed on conserving traditional varieties of seeds and biodiversity, through farmer-based evaluation and community or local gene banks (see Chapter 6).

The FAO 2002 report on organic agriculture highlights the important contributions of poor farmers worldwide [16]. Non-certified organic agriculture, practiced by millions of indigenous people, peasants and small family farms makes a significant contribution to regional food security. In Latin America they account for more than 50 percent of the maize, beans, manioc and potatoes produced; in Africa, most of the cereals, roots and tubers; in Asia, most of the rice. Case studies from India, Brazil, Iran, Thailand and Uganda show how traditional knowledge, innovation and agro-ecological approaches have brought numerous benefits: increased productivity, better environmental health and soil fertility, improved biodiversity, economic benefits, food security, enhanced social relations within communities, and revival of traditional, sustainable agricultural practices.

Farmers in Ethiopia have been taking steps to ensure their food security by relying on their knowledge [17]. In Ejere, farmers have reclaimed their own varieties of local wheat, teff (an Ethiopian staple cereal) and barley, after so-called modern high-yielding varieties actually resulted in lower yields and other problems (see Chapter 2). In the Butajira area, farmers are demonstrating that it is possible to farm intensively and sustainably to provide enough food to meet



Terraced fields in the Andes

population needs. They do this by using indigenous crops selected for resistance to diseases, drought tolerance and many other desirable features, by intercropping and by integrating livestock management. In Worabe, farmers are maintaining a complex, sustainable and indigenous agricultural system that ensures food security. The system is based on enset, a very drought resistant, multiple-use indigenous crop. The success of the Tigray project (Chapter 11) bears further witness to the overriding importance of putting farmers first in sustainable food production.

Better incomes, increased food security

Evidence from hundreds of grassroots development projects shows that boosting agricultural productivity with agro-ecological practices not only increases food supplies, but also means more income and access to food, less poverty and malnutrition and more secure livelihoods [18]. Agro-ecological systems give more stable levels of total production per unit area than high-input systems and provide more economically favourable rates of return for labour and other inputs that benefit small farmers and their families. They ensure soil protection and conservation, and enhance agro-biodiversity [19] (see Chapter 18).

Integrated production systems and diversified farms have helped farmers in south-central Chile reach year-round food self-sufficiency while rebuilding the land's productive capacity [5]. Small, model farm systems were set up, consisting of polycultures and rotating sequences of forage and food crops, forest and fruit trees, and livestock. Soil fertility improved, and no serious pest or disease problems have appeared. Fruit trees and forage crops achieved higher than average yields, and milk and egg production far exceeded that on conventional high-input farms. For a typical family, such systems produced a 250 percent surplus of protein, 80 and 550 percent surpluses of vitamin A and C, respectively, and a 330 percent surplus of calcium. If all the farm output were sold at wholesale prices, a family could generate a monthly net income 1.5 times the monthly minimum wage in Chile, while dedicating only a few hours per week to the farm. The time freed up could be used for other income-generating activities.

Organic agriculture improves income, profitability and return on labour by removing or reducing the need for purchased inputs; by diversification (often adding a new productive element) and optimising productivity; by maintaining or improving on- and off-farm biodiversity, allowing farmers to market non-cultivated crops, insects, and animals; and by sales in a premium market [20]. A case study from Senegal showed that yields could be increased manifold, and were less variable year on year, with consequent improvements in household food security. Likewise, a participatory fair-trade coffee cooperative in Mexico, which adopted organic practices, allowed smallholder coffee growers to overcome soil degradation and low yields, and

access a speciality market.

Generating money for the local economy

Analysis of the money flows of an organic box scheme from Cusgarne Organics (UK) demonstrated how buying local benefits the community [21]. The analysis followed the trail of the farm box scheme income, monitoring exactly where the money was spent, how much of it was 'local' expenditure, and then tracked that money to the next layer of spending. It is estimated that for every £1 spent at Cusgarne Organics, £2.59 is generated for the local economy. In contrast, a study involving supermarket giants Asda and Tesco found that for every £1 spent at a supermarket, only £1.40 is generated for the local economy. The study concludes, "The figures demonstrate that the net effect of spending at Cusgarne Organics to the local economy is nearly double the effect of the same amount spent with out-of-county and national businesses."

Food production for local consumption is also sustainable because it cuts down on food transport and the tremendous social and environmental costs that entails (see Chapters 8 and 19).



Locally produced cheeses in London

- 23 -

Stem Farmers' Suicides with Organic Farming

Amid a rising epidemic of farmers' suicides in India, an organic farmer appeals to the father of the Green Revolution to embrace organic agriculture



Bhaskar Save in his workshop

UN slams India for farmer suicides

India has enough food to feed her population of one billion, yet hunger and food insecurity at household level increased at the end of the 20th century. A recent UN report casts doubt on the Government's claim that poverty declined from 36 to 26 percent between 1993-2000. The UN Special Rapporteur on the Right to Food, Jan Ziegler reports that the poorest 30 percent of Indian households eat less than 1 700 kilo calories per day, well below the international minimum standard of 2 100 kilo calories per day, despite spending 70 percent of income on food [1]. Furthermore, over half India's women suffer severe malnutrition, and over 47 percent of children are underweight. These figures are higher even than most countries in poverty stricken sub-Saharan Africa. Ziegler blames the focus on cash crops for a more export-orientated economy that has reduced the availability of grains, pulses and millets for household consumption. The shift to cash crops

requires increasingly expensive inputs such as seeds and fertilizers, which has caused massive and often fatal debts for farmers. The report explicitly links the incidence of thousands of farmer suicides in India to the unremitting growth of a market economy that does not benefit all Indians equally.

Impassioned plea to India's government

Bhaskar Save is an 84-year-old farmer from Gujarat who has petitioned the Indian Government to save India's farmers from exploitation and worse. In an open letter to Prof M.S. Swaminathan (chairperson of the National Commission on Farmers in the Ministry of Agriculture) he puts the blame squarely on his shoulders as the 'father' of the 'Green Revolution' that has destroyed India's natural abundance, farming communities, and soil [2]. He writes: "Where there is a lack of knowledge, ignorance masquerades as science! Such is the 'science' you have espoused, leading

our farmers astray – down the pits of misery.”

The Green Revolution defines the forty years after India's independence in 1947 when technology was widely introduced into agriculture. Farmers came under intense pressure to provide marketable surpluses of the relatively few non-perishable cereals to feed the ever-expanding cities. Since then, India's integration into the global economy has served transnational corporate interests championed by the World Bank, the IMF, and the WTO, but not the millions of her farmers who are in a state of crisis [3]. Fifteen years of market reforms guided by the international financial superstates has contributed to rising unemployment, decreased income for agriculturalists and labourers, unpayable debts, and loss of land to creditors [4].

A silent revolution of suicide

Mumbai and Bangalore have benefited from the boom in the information technology sector that contributes an eight percent growth to India's economy each year [5]. The two cities are now poised to take advantage of the boom in the biotech industry. But the picture of “India Shining” touted by an expensive government backed media campaign overlooks the rural areas being torn apart at the roots by a second wave of agrochemicals, genetically modified seed and pesticides that have subsumed the Indian countryside with devastating effect. The countryside is home to three quarters of India's population.

The second ‘Gene Revolution’ in agriculture is proving more deadly in the wake of the first. The cost of taking on the extra burden of gene biotechnology is too much to bear. Farmers unable to pay back debts incurred by the purchase of seed pesticides, fertilizers and equipment, are forced to kill themselves at a rate of two per day. In despair some drink the chemical pesticides, while others burn, hang, or drown themselves. At a help centre set up to monitor farmer suicides in Vidarbha region in the central state of Maharashtra, black skulls mark the number of dead farmers on the map. There are 767 skulls clustered together that were pinned up in fourteen months to August 2006. Farmers have also resorted to selling a kidney to pay back debts. India's agricultural minister Sharad Pawar acknowledged in Parliament that a total of 100 000 farmers have committed suicide between 1993-2003 [6]. A further 16 000 farmers per year on average are said to have died since then. Bhaskar Save writes: “You, M.S. Swaminathan... More than any other person in our long history it is you I hold responsible for the tragic condition of our soils and our debt-burdened farmers, driven to suicide in increasing numbers every year.”

The cost of GM cotton kills farmers

A citizen's jury discovered that seventy percent of farmers that died were farming Monsanto's Bt cotton [7]. Crop failures on a repeated scale have ruined the reputation of the once profitable crop known as “King Cotton”. Indian farmers have

coined the new name “Killer Cotton” not just because of the increasing costs of inputs, but because the State cut its guaranteed purchase price by 32 percent, and buys less of the harvest than before, which leaves farmers vulnerable to a buyers monopoly. This diminished investment in agriculture by Government has also reduced institutional credit available to farmers. Further pressure for the farmer is competition from foreign trade that give heavily subsidized US cotton an advantage. Farmers are actively encouraged by agricultural officials to increase productivity by borrowing money to buy Monsanto's expensive GM cottonseed. Even when the Indian Government forced Monsanto to cut royalties they receive for the patented seeds, Monsanto appealed to the Supreme Court. It is estimated that Indian farmers are losing \$26 billion annually.

The final nail in the farmers coffin are the untenable debts for the GM products that have proved disastrous for the small, non-irrigated plots common to most of India's hundreds of millions of farms [8]. (see chap 2) Every year the farmer must take out a fresh load to buy seeds, fertilizers, pesticides, etc but first he has to pay off the previous year's loan with interest. According to Gene Campaign [7] production costs have risen to over 100 percent and the farmers who are unable to recover even the production costs are the ones to suffer in the equation.

To make matters worse, Indian Prime Minister Manmohan Singh and US President George Bush agreed the Knowledge Initiative in Agricultural Research and Education in March 2006 that will ultimately bring Indian agriculture under the control of US corporations like Monsanto [6].

Political pressure to adopt GM crops

The Indian government's ability to protect farmers, consumers and the environmental health from the risks of GM crops has been called into question by its critics [9]. It is hoped that the recent Supreme Court of India's decision to ban any further GM crop trials until further notice [7] will force the government to rethink its biotechnology strategy. Unfortunately, existing GM cotton trials are not included in the ban despite the health hazards to humans and livestock [10, 11]. Prime Minister Singh has now invested a hefty Rs 160 billion in a debt relief package to persuade farmers in the poverty stricken, high-risk suicide areas of Andhra Pradesh, Karnataka, Kerala and Maharashtra to continue farming [12]. The package consists of loans, interest waivers, seed replacement, minor irrigation schemes, and subsidiary incomes for farming livestock, dairying and fisheries. Sadly, the investment comes too late for those farmers that have already died. Many more have already turned their backs on the perils of Bt cotton farming to regain their health and independence [13]. (See chap 14)

Agricultural education models unsustainable

Perhaps it is not surprising that farmers fall for the promise of increased productivity by buying the

long list of equipment from the agribusiness salesman. According to Bhaskar Save, of the 150 agricultural universities in India that own thousands of acres of land, not one grows any significant amount of food to feed its staff and pupils. Instead the focus is on churning out hundreds of graduates each year to tell farmers what they must buy to increase productivity, not what they must do to ensure the sustainability of the land for future generations.

“Nature, unspoiled by man, is already most generous in her yield. When a grain of rice can reproduce a thousand-fold within months, where arises the need to increase its productivity?” Save asks Swaminathan.

Natural abundance in an organic orchard

In contrast, Save’s own orchard-farm “Kalpavruksha”, near the coastal village of Dehri close to the Gujarat-Mararashtra boarder, has become a “sacred university” specialising in natural abundance, or Annapurna [14]. Every Saturday afternoon the farm gates open to farmers, agricultural scientists, students, senior government officials, and city dwellers, who come to share Save’s philosophy and practice of natural farming: “Co-operation is the fundamental Law of Nature.”

The high yields in the organic orchard easily out-perform any farm using chemicals and this is apparent to its many visitors. Masanobu Fukuoka, the renowned Japanese natural farmer said: “I have seen many farms all over the world. This is the best. It is even better than my own farm.” The coconut trees produce an average of 400 coconuts per tree annually; some produce more than 450 coconuts, and are among India’s highest yielding trees. There is an incredible variety of fruit trees: banana, papaya, mango, lime, tamarind, pomegranate, guava, custard apple, jackfruit, date, and chikoo (similar to lychee) that produce an average of 300-350 kg of delicious fruit per tree each year.

Fruit trees are also planted on soil platforms raised by Save above the rice crop in low-lying paddy fields. Between every two adjacent platforms are trenches that act as irrigation channels in the dry season and drainage in monsoon. As the trees grow, the trenches are placed further away from the trunks to encourage the roots to spread out to optimise water efficiency. This pioneering feature of his work has greatly increased yield, and attracted attention all over the world.

Biodiversity is essential to soil health

Diversity of plant life is the key factor on organic farms. Save simultaneously plants short life-span (alpa jeevi), medium life-span (madhya-jeevi), and long life-span (deergha-jeevi) species. The community of dense vegetation ensures that the soil’s microclimate is well moderated all year round. The groundcover provides shade on hot days, while leaf litter (mulch) cools and slightly dampens the surface of the soil. On cold nights it serves as a

blanket that conserves heat gained during the day. High humidity under the canopy of mature long-life trees reduces evaporation, and minimizes the need for irrigation. The drooping leaves of plants act as a water metre to indicate falling moisture levels.

Save grows a tall, native variety of rice, Nawabi Kolam, that is rain-fed, high yielding, and needs no weeding. After harvest, he seasonally rotates several kinds of pulses, winter wheat and some vegetables on the paddy field that grow entirely on the sub-soil moisture still present from the monsoon. When they too are harvested, cattle can browse the crop residue and provide dung fertilizer to further enrich the soil for the next cycle of planting.

The polyculture model produces a year round continuity of harvests. First from the short life-span species such as the various vegetables, and then from the medium life span species such as banana, custard apple and papaya, until the long life-span species of coconut, mango and chickoo begin to bear fruit. It provides self-sufficiency for a family of ten (including grandchildren) and an average of two guests from a modest two-acre plot. Most years, a surplus of rice is gifted to relatives or friends.

Signs of hope in a story of change

Bhaskar Save was not always an organic farmer. At first, he used chemical fertilisers together with dung manure for his vegetable plants and rice paddy. His rice harvest was so good that it attracted the attention of the Gujarat Fertilizer Corporation. They asked him to teach other farmers to use the chemical fertilizers for which he received 5 rupees for every bag he sold. He quickly became a “model farmer” for the new technology while earning enough to extend the acreage of his farm. Soon he realised that he was caught in a cycle of spending more money to use more chemicals to maintain productivity. Inspired by Mahatma Gandhi and his successor Vinoba Bhave, he adopted some of the farming methods of the Adivasi, the tribal majority of India’s rural population. From then on his costs reduced and the soil flourished. By 1959-60 he abandoned chemicals altogether.

Save has learned his major lesson:

“By ruining the natural fertility of the soil, we actually create artificial ‘needs’ for more and more external inputs and unnecessary inputs for ourselves, while the results are inferior and more expensive in every way. The living soil is an organic unity, and it is this entire web of life that must be protected and nurtured”

Water and food security depends on soil

Save has updated a traditional intercrop system specifically for growing cotton in low rainfall areas (see Fig 23.1.) The six integrated crops are harvested in stages during a 365-day cycle: two types of millet, three kinds of edible pulse legumes, and cotton. Every other row of legume crops provides nitrogen to the soil. Weeds

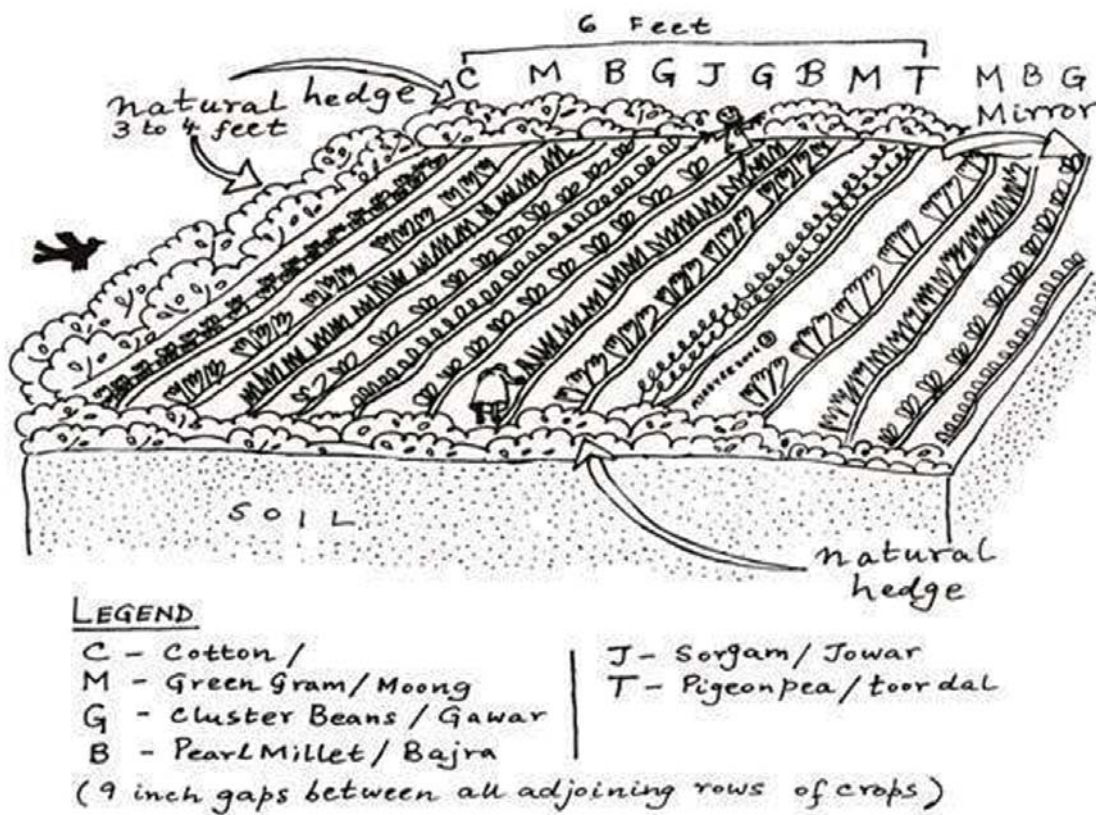


Figure 23.1. Save's system

that attract predators that feed on crop damaging species are welcome. So are worms that aerate and provide compost, and nutrient rich soil microorganisms. All are the natural keepers of soil health. As this system needs no irrigation, it is crucial that chemicals are not added as they diminish the soils capacity to absorb moisture.

For millennia organic farming was practiced in India without any marked decline in soil fertility. In areas where polyculture is replaced by monocrops such as sugarcane and basmati rice the soil is ruined by the excessive use of water irrigation.

Thick crusts of salt (salinisation) progressively form on the waterlogged land where roots rot. Supplying huge amounts of water for refined sugar that requires 2 to 3 tonnes of water per kilo has encouraged extensive dams and river linking schemes by industry. These short-term solutions displace people and wreak devastating ecological consequences.

In contrast, organic farming practice is light on irrigation. The best yields come from soil that is just damp. Porous soil under Save's organic orchard of mixed local crops acts like a sponge, soaking up the huge quantities of monsoon rains that percolates down to the ground water table. He recommends restoring a minimum of 30 percent of mixed indigenous trees and forests to India within the next 20 years to prevent the impending threat of water scarcity. Storing water underground in natural reservoirs is the way forward to ensure food and water security.

It is predicted that by 2030, that India's water table would have receded by 70-160 ft, in two thirds of the region unless something is done about wasteful water practices [7]. In Andhra Pradesh it is estimated that there are nine times more wells than there was in 1975, many of which have dried up. In Punjab some 80 percent of

groundwater blocks are over exploited.

As Save points out, "More than 80% of India's water consumption is for irrigation, with the largest share hogged by chemically cultivated cash crops. Most of India's people practising only rain-fed farming continue to use the same amount of ground water per person as they did generations ago."

A real revolution for India's farmers

In response to the rising numbers of farmer's suicides, which are clearly a manifestation of great agricultural distress, Swaminathan is reported to have said [7],

"This crisis is unparalleled since independence and reminiscent only of the agrarian crisis of pre-war and war days." And "In a country with a high prevalence of poverty and malnutrition, the government should always retain a commanding position in the management of the food security system."

Bhaskar Save's method of mixed short to long life span intercrops on plots as small as two acres demonstrate that it is possible to regenerate even barren wastelands in less than ten years. His model of organic, self-sufficient farming offers a sustainable and equitable alternative to transnational corporations that threaten to impose a new kind of serfdom with patented biotech crops on India's small farmers who are already in peril. Save's sixty years of farming experience shatters the illusion that farmers can boost productivity and profits only by increasing inputs of agrochemicals and engineered seeds. Swaminathan must embrace organic farming models when co-ordinating the new Agricultural Policy to restore food sovereignty to Indian farmers and to create food security for all.

- 24 -

Organic Farmer Who Values His Freedom Above All

Moses & Mary Mulenga work hard on their organic farm and are richly rewarded in ways other than simply financial

Moses and Mary Mulenga were bursting with pride and enthusiasm as they showed us around their farm, medium-scale by Zambian standards. They have a total of 14.9 ha, 9.5 of which are cultivated and the rest left as woods for keeping bees.

On a makeshift table were 14 bags of seeds all cultivated on the farm; as green manure, ground cover between crops, or food.

"We used to do 17 crops," said Moses.

Moses explained that they have a basic two-year rotation between green manure and food crops, using ground cover crops "to improve fallow" in between. But they also rotate between plots; so I gathered that for any single plot, the rotation period is 12 years.

Green manure crops consist of four varieties of

velvet beans (white, black, black- summerset, and green), sunhemp, and black sunhemp. Why so many? Simply "to maintain the varieties", Moses said. The different varieties have different uses for controlling insect pests or for improving soil. Green velvet beans, for example, are good for acid soils. The ground cover crops are *Sesbania sesban* and *Tephrosia*, and the food crops are cowpeas, soybeans, red sorghum, a local open-pollinated white maize variety, pigeon peas and groundnuts.

Moses said he never grows hybrid maize because they give poorer yields than the indigenous white maize variety. He has increased the yield of white maize from 2 tonnes per ha when he was using conventional farming methods to 3 tonnes per ha when the farm became fully organic.



Moses has not been a farmer for long. He used to work for Zambian Airways in ground transport. But one day in 1995, he and his fellow workers went to work only to find the gates firmly shut, the airline had gone out of business.

So he decided to become a farmer instead, something he had always wanted to do, as his father was a farmer.

He started to farm conventionally and "almost gave up", because he had great difficulty making ends meet.

At that point, Brother Paul of the Kasisi Agricultural Training Centre invited Moses to come and see what they were doing at the Centre (see Chapter 17). After a week's training on sustainable agriculture in Kasisi in 1996, Moses started to reduce pesticides and fertilizers, substituting for organic inputs until he stopped applying agrochemicals completely in 1998 and became fully organic.

"The most important thing for me is the freedom I now have," said Moses, "I don't have to depend on loans, I can grow whatever crops I like, save and replant my own seeds."

The farm provides all the needs of his household, for him, his wife, and their five teenage sons aged thirteen to nineteen. All the sons are attending school, which is quite an achievement, as Zambia does not have free education, and few farmers can afford to send their children to school. Apart from all the food they eat, the family makes about 12 million Kwachas (US\$3 000) a year selling seeds.

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Moses and Mary took us first to see their compost heaps. There were several rectangular mounds on the ground, some covered over with a polythene sheet. "To make a compost heap, you must prepare the ground beneath the compost by poking holes in it to improve aeration, then you find some small branches or twigs of trees, such as pigeon peas, *Sesbania sesban*, which rot easily, and lay it on the ground," Moses explained, "then you layer it with dry material such as dry grass, velvet beans, etc followed by green materials, and then manure, and keep on piling up the layers until it is no higher than you can reach to water the whole pile."

"Now, you see this long stick poking out from the pile?" He said as he pointed to a long straight branch sticking out from the top of one side, which looks as if it is buried diagonally deep into the pile. "This is how you know if the compost is working properly. You take it out and feel the end of the stick; if it is warm, the compost is working properly." He asked Mary to demonstrate, which she did, elegantly and with obvious pleasure in showing off.

Next, they took us around the fields, some of

which have been harvested, and lots of crop residues have been left on the ridges "to improve the soil and retain moisture", Moses explained. I asked if the ridges were permanent, and he said yes. So they have adopted some practices from conservation farming as well as being organic; which goes to show how farmers are learning from one another, and innovating all the time.

"The most important thing for me is the freedom I now have," said Moses, "I don't have to depend on loans, I can grow whatever crops I like, save and replant my own seeds."

We went finally into the woods, which consisted of relatively small trees and shrubs, obvious re-growths from a previously cleared area. Across a wire fence was barren land with a few isolated trees left standing.

"We had to put up this fence," said Moses, "Before we did that, people would come in and clear away our trees, as they are still doing with the land out there." They chop down the trees for no other reason than to obtain firewood.

Soon, we came upon a rectangular wooden box about 1.5 metre x 0.5 m x 0.3 m mounted on bricks in a small clearing among the trees.

"This is a small hive with about 35 000 bees," Moses revealed. "It is harvested two times a year, in June and again in October, each harvest giving about 35 litres of honey, or 70 litres per year. We leave some for the bees of course, so they can feed their babies."

There are five hives in the woods, three giving 100 litres a year. Selling the honey from one hive is sufficient to pay school fees for one child for a whole year

There are five hives in the woods, three giving 100 litres a year. Selling the honey from one hive is sufficient to pay school fees for one child for a whole year

As we were walking back after the brief tour, I asked Mary if she and her husband enjoy farming. "Oh yes, we like it very much." she said emphatically.

"How many hours do your work a day?"

"We work for eight hours in the morning, and five in the afternoon," she said.

"Every day of the year?"

"Everyday in the months of November and February," she answered.

"Do you have any help at all?"

"No, except from the boys during the holidays."

That too, is characteristic of organic farmers. They work quite hard, at least partly because they love farming so much.

Special Practices and Systems

- 25 -

Greening the Desert How Farmers in Sahel Confound Scientists

Scientists are catching up with farmers on how local knowledge and cooperation can work miracles



Scientists catch up with reality

For years, many scientists have been making dire predictions of widespread irreversible 'desertification' in the African Sahel. But recent findings have proven them wrong.

Satellite images consistently show an increase in 'greenness' since the 1980s over large areas, confirming evidence on the ground indicating that

the Sahel has recovered from the great droughts of the 1980s, and that human factors have played a large role in reclaiming the desert [1].

The African Sahel is a semi-arid grass and shrubland region situated between the Sahara desert in the north and the humid tropical savannas in the south, with a steep north-south gradient in mean annual rainfall. Rainfall is

markedly seasonal and variable. A long dry season alternates with a short humid season during the northern hemispheric summer. The scarcity of rainfall and its variable, unpredictable pattern accentuating from south to north, are the most important controlling factors of the Sahel ecosystem. The vegetation cycle closely corresponds to the seasonality in rainfall, with virtually all the plant growth in the humid summer months. The sharp seasonal contrasts in rainfall are overlain by considerable fluctuations from year to year, and from one decade to another.

Although variable rainfall and droughts are seen as normal in arid and semiarid climates, the droughts that struck the Sahel in the late 1960s through to the 1980s were unprecedented in length and severity. Land degradation and famine during the droughts, exacerbated by political instability and unrest, prompted the UN to hold a conference on desertification in 1977. This initiated a debate, still ongoing, on the causes and effects of drought, land degradation and desertification.

There are two opposing camps in the debate. Adherents of the desertification hypothesis hold human activities responsible for 'irreversible' declines in vegetation from 'overuse of resources' and 'human mismanagement'. Sceptics, however, see declines in vegetation as the result of drought, and hence a temporary phenomena, with humans playing only a minor role, if at all. Some scientists have stressed the high potential of adaptation of the Sahel population to rainfall variability.

Greenness correlates with rainfall

Scientists at the University of Arizona Tucson, University of Maryland Baltimore and NASA Biospheric Sciences Branch Greenbelt in the United States investigated the spatial and temporal patterns of vegetation greenness and rainfall in the African Sahel. For rainfall, they used available meteorological data. For greenness, they used imaging data derived from measurements made by the Advanced Very High Resolution Radiometer instrument on board the National Oceanic and Atmospheric Administration polar-orbiting satellite series. To measure greenness, the researchers used Normalised Differential Vegetation Index (NDVI), the normalised ratio of the near-infrared (NIR) and red spectral reflections:

$$\text{NDVI} = (\text{NIR} - \text{red}) / (\text{NIR} + \text{red})$$

NDVI is sensitive to the presence, density and condition of vegetation and is correlated with the absorbed photosynthetically active radiation and growth in vegetation.

For the period 1982-2003, the overall trend in monthly maximum NDVI is positive over a large portion of the Sahel region, reaching up to 50 percent increase in the average NDVI in parts of Mali, Mauritania and Chad, though averages are not very meaningful in this highly dynamic environment with considerable seasonal fluctuations. This positive trend in NDVI is accompanied by widespread increases in rainfall over the same period of time, with maximum

positive slopes in northern Nigeria.

However, from a longer-term perspective, the observed increase in rainfall is merely a return to more or less average conditions that prevailed before the 1960s after an exceptionally dry period, and does not suffice to cancel out the secular downward trend in rainfall across the entire region. The early to mid 1980s saw the peak of desiccation in the Sahel for the century.

Monthly maximum NDVI in the Sahel was found to correlate best with rainfall accumulated over a period 3 months (current plus previous 2 months), which confirmed earlier findings that vegetation greenness in semi-arid environments is more strongly related to soil moisture - a function of rainfall accumulated over a period of time - than to instantaneous rainfall. Correlation coefficients computed for NDVI and rainfall are highly significant for the entire Sahel region ($P < 0.05$) with stronger correlations in the southern Sahel than in the north.

Greenness 'hotspots' correlate with human activity

When the main correlation of NDVI to rainfall is subtracted out, there is a residual pattern of NDVI in which large areas are without significant trends (over and above that predicted from the trends in rainfall), and considerable areas of positive residual trends, i.e., areas in which the vegetation has been greening up more than explained by rainfall alone. These positive 'hotspots' are found in parts of Senegal, Mauritania, Mali, Niger, the Central Plateau of Burkina Faso and large portions of Chad.

While the greening in the Niger Delta of Mali might be explained by an expansion of irrigation, different explanations must be found for the Central Plateau of Burkina Faso, which had been identified as a prime example of desertification crisis some 20 years ago. Here, a recovery of vegetation greenness beyond what would be expected from the recovery of rainfall alone might be due to increased investment and improvements in soil and water conservation technique such as contour bunding, in response to the drought crisis experienced by farmers [2].

In Niger, hotspots were observed in Tahoua and Maradi regions, centring around the area of Projet Keita, an extensive rural development programme with a focus on natural resource management and soil and water conservation which began in the early 1980s supported by the FAO and the World Food Programme of the UN as well as the governments of Niger and Italy. Chris Reij, a soil conservationist who has worked in the region for decades, has independently corroborated the farmer-managed natural regeneration in this region of Niger, particularly along the road between Maradi and Dosso.

In Chad, the greening hotspot was found, among other places, in the Chari-Baguirmi region. The West African Pilot Pastoral Programme has managed a few sites there since 1994 to test a participatory approach to holistic rangeland management [3]. Pastoralists have evaluated the outcome as positive.

Areas showing negative trends in the NDVI residuals cover a considerably smaller area of the Sahel [1] and are clustered in northern Nigeria and Sudan, particularly in northern Nigeria. A hypothetical explanation may be human-induced land degradation due to civil strife and conflict. But overall, the 'negative' impacts of human activity are insignificant.

More supporting satellite evidence

Another study of satellite images supported the notion that more plants make more rain [4, 5]. Evidence was found for a positive feedback between vegetation and rainfall at the monthly time scale, and for a vegetation memory operating at the annual time scale. That means greater greenness the previous month tends to increase rainfall a month later, and a green year tends to increase rainfall the next year, as greater plant growth and deeper root systems tap into more ground water for making rain.

This positive interaction between vegetation and rainfall increases the inter-annual variation in rainfall, accounting for as much as 30 percent of the variability in annual precipitation in some regions of the Sahel.

As a commentator stated [4]: "The result adds to the impetus to preserve green spaces in dry regions, in order to help prevent deserts from growing and encroaching on agricultural land."

Evidence emerging from the ground

Evidence of recovery has been coming from the ground since at least the beginning of the present century. Fred Pearce reported in the *New Scientist* in 2001 on how in Nigeria, Niger, Senegal, Burkina Faso and Kenya, integrated farming, mixed cropping and traditional soil and water conservation methods have been increasing per capita food production several fold, keeping well ahead of population growth [5].

The use of sheep manure for fertiliser gave increased yields for farmers in Kano, Nigeria. Planting leguminous crops increased nutrient levels in the soil by fixing nitrogen from the air. Integration of crops and livestock enhances nutrient cycling; legumes and manure return to the soil what crops take out. The Kano region is the most agriculturally productive part of the country, with increased yields of sorghum, millet, cowpeas and groundnuts.

A 4-year study in eastern Burkina Faso challenged the assumption that land is degrading largely due to human activities [6]. It found that despite declining rainfall since the late 1950s and increasing populations, there was no evidence of land degradation connected to human activities nor a decline in food productivity. Conversely, yields of many crops have risen, and there was no decline of soil fertility over 30 years.

These farmers did not achieve environmental sustainability through a capital-intensive or high-tech path. In Burkina Faso, the increased yields of sorghum, millet and groundnuts could hardly be attributable to increased external inputs, because these crops received little fertilizer and were cultivated largely with a hand hoe.

The scientists found that farmers have a rich repertoire of soil and water conservation technologies, such as crop sequencing, crop rotation, fallowing, weeding, selective clearing, intercropping, appropriate crop and landrace selection, plant spacing, thinning, mulching, stubble grazing, weeding mounds, paddocking, household refuse application, manure application, crop residue application and compost pits. Mechanical practices include perennial grass strips, stone lines, wood barriers, earth barriers, brick barriers, stalk barriers, stone bunds, earth bunds and living hedges.

These positive 'hotspots' are found in parts of Senegal, Mauritania, Mali, Niger, the Central Plateau of Burkina Faso and large portions of Chad. Many of these are due to increased investment and improvements in soil and water conservation techniques in response to the drought crisis

Perhaps more important than the practices is the selective way they are used, which vary with different field types, allowing optimal adjustment of limited labour and inputs to the requirements of different crops and soils. If land becomes limited, farmers do not need to invent new management systems; they apply these soil and water conservation practices more intensively. Farmers also apply land management practices only when and where needed. Using their knowledge of crops and soils, they treat only the parts of their field that need particular attention at any one time.

High local population densities, far from being a liability, are actually essential for providing the necessary labour to work the land, dig terraces and collect water in ponds for irrigation, and to control weeds, tend fields, feed animals and spread manure [5]. As population densities increase, farmers intensify their cooperation systems, grouping to tend each other's fields at busy periods, lending and borrowing land, livestock and equipment, and swapping seed varieties.

Another study of satellite images supported the notion that more plants make more rain. A greater greenness the previous month tends to increase rainfall a month later, and a green year tends to increase rainfall the next year, as greater plant growth and deeper root systems tap into more ground water for making rain

People thus invest heavily in creating and maintaining social networks that share land, labour, seeds, cattle grazing bushland, technologies and cash [6]. These networks enhance the ability of farmers to farm sustainably and efficiently by cooperation and reciprocity. They also allow people to diversify their livelihoods, learn from each other, and minimize risks, thus avoiding poverty traps.

Furthermore, in Maradi district of southern Niger, where repeated droughts have wrought environmental damage, farmers have reversed the damages and reclaimed the desert [5]. This was also true of Machakos (renamed Makueni) district of Kenya. In the 1930s, British colonial scientists had condemned the bare eroding hills of the

drought-prone area to environmental oblivion; likewise the local Akamba people were seen as doomed to a miserable poverty-rife existence. The same narrative was consistently reproduced in the 1950s and 1970s. Yet researchers found the hills greener, less eroded and more productive than before, despite a fivefold population increase. The Akamba had responded to the droughts by switching from herding cattle to settled farming, giving them incentive to work the land effectively.

From colonial times, all trees in Niger had been property of the state, which gave farmers little incentive to protect them, and they were chopped for firewood or construction. Over time, farmers began to regard the trees in their fields as their property, and in recent years, the government has recognized the benefits and allowed individuals to own trees. Farmers make money off trees by selling branches, pods, fruit and bark

Niger a haven of trees

In Niger today, millions of trees are flourishing, thanks to poor local farmers. There are at least 3 million tree-covered hectares, not the result of the large-scale planting or other expensive methods often advocated by African politicians and aid groups, but by the efforts of individual farmers themselves. The area is far greener than it was 30 years ago; and these gains have come at a time when the population of Niger has exploded.

How did all this come about? Lydia Polgreen told the story in the Herald Tribune [7]. About 20 years ago, farmers like Ibrahim Danjimo realized something had to be done. "We look around, all the trees were far from the village," he said, "Suddenly, the trees were all gone."

Danjima, now in his 40s, has been working the rocky, sandy soil of his tiny village since he was a child. He and other farmers in Guidan Bakoye took a small but radical step of not clearing the saplings from their fields before planting as they had for generations. Instead, they would protect and nurture the saplings, carefully ploughing around them when sowing millet, sorghum, peanuts and beans.

Another change was the way trees were regarded by law. From colonial times, all trees in Niger had been property of the state, which gave farmers little incentive to protect them, and they were chopped for firewood or construction.

"This is no high-tech break through, nor a result of Western aid programmes." The greening of Sahel is a clear example of how the dominant Western knowledge system had grossly misinformed policy-makers; and it was the knowledge and initiatives of local farmers that saved the situation

Over time, farmers began to regard the trees in their fields as their property, and in recent years, the government has recognized the benefits and allowed individuals to own trees. Farmers make money off trees by selling branches, pods, fruit and bark.

Mahamane Larwanou, a forestry expert at the University of Niamey in Niger's capital, said the

revival of trees had transformed rural life. Farmers can sell the branches for money, they can feed the pods as fodder to their animals, sell or eat the leaves and fruits. The tree roots fix the soil in place, preventing it from being carried off with the fierce Sahel winds. The roots also help hold water in the ground rather than letting it run off into gullies that flood villages and destroys crops.

"Wrestling subsistence for 13 million people from Niger's fragile ecology is something akin to a puzzle." Larwanou said, "Less than 12 percent of the country's land can be cultivated, and much of that is densely populated. Yet 90 percent of Niger's people live off agriculture, cultivating a semiarid strip along the southern edge of the country."

Farmers practise mostly rain-fed agriculture. The return of trees increases the income of rural farmers, cushioning them against the boom and bust cycle of farming and herding.

Ibrahim Idy, a farmer in Dahirou, a village in the Zinder region, has 20 baobab trees in his fields. Selling the leaves and fruit brings him about \$300 a year in additional income. He has used that to buy a motorized pump that draws water from his well to irrigate his cabbage and lettuce fields, and sends his children to school. His neighbour, who has fewer baobab trees, cannot send his children to school; instead they have to draw water from the well. In some regions, swaths of land that had fallen out of use are being reclaimed with labour-intensive but inexpensive techniques.

In the village of Koloma Baba, in the Tahoua region just south of the desert's edge, a group of widows has reclaimed fields once thought forever barren. They dug pits in plots of land as hard as asphalt, placed a shovel of manure in each pit and wait for rain. The pits held the water and manure stay in the soil and regenerate its fertility. In this way, more than 240 000 ha of land have been reclaimed, according to researchers. But it is still hand to mouth, the women produce enough to eat, and disaster is always just one missed rainfall away.

While Niger's experience of greening on a vast scale is unique, smaller tracts of land have been revived in other countries. "It really requires the effort of the whole community," said Larwanou. "If farmer don't take action themselves and the community doesn't support it, farmer-managed regeneration cannot work."

Moussa Bara, the chief of Dansago, a village in the Aguié region where the regeneration has been a huge success, said the village had benefited enormously from the revival of trees. He said not a single child had died of malnutrition in the hunger crisis that gripped Niger in 2005, largely because of extra income from selling firewood. Still, he said, the village has too many mouths to feed.

Project Oasis must remain farmer-led

Chris Reij, now at the Free University Amsterdam in the Netherlands, presented the findings in Niger at the From Desert to Oasis symposium in Niamey. He wants to spread the success of Niger to neighbouring countries including Mali, Senegal and Burkina Faso. The programme will form part

of the Oasis initiative to reclaim deserts, which was launched at the symposium in October 2006 by 11 African countries, with support from international research and government agencies [8].

Let's hope they will continue to let local farmers lead the projects, with scientists taking a supporting role. As Fred Pearce stressed of the Sahel miracle [5], "This is no high-tech breakthrough, nor a result of Western aid programmes." A major reason for the overestimation of land degradation is the underestimation of local farmers' abilities [6]. Scientists, policy-makers and

aid workers must recognize the overriding importance of local knowledge and ingenuity for innovation, and well as the cooperative community networks for solving our problems of survival in times of climate change.

The greening of Sahel is a clear example of how the dominant Western knowledge system had grossly misinformed policy-makers; and it was the knowledge and initiatives of local farmers that saved the situation.



Chad Dancers

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One Bird Ten Thousand Treasures

Ducklings in paddy fields turns weeds into resources and increases yield and leisure for farmers



During the last leg of a six-day lecture tour in Japan 1999, I was fortunate enough to have visited an organic farmer not far from Fukuoka, who was reputed to have done wonders introducing ducks into the rice paddy field.

The train ride from Tokyo lasted five and a half hours, speeding through a most unusual landscape, which repeats itself in endless variations for the entire duration. It consists of large and small clusters of houses and the occasional single abode, all floating, it seems, on a sea of paddy fields. Paddy fields fill every available inch of land that is not built upon, and most of the plots are tiny. That was a real surprise for me, who, like most people, imagine Japan to be a fully industrialized developed nation.

Our hosts from the Green Co-op in Fukuoka met us at the station, and after the usual polite exchange of bows, we were taken to another platform for the local train to Keisen, where the famous organic farmer Mr. Takao Furuno had kindly invited all three of us: Tony Boys, my

interpreter for the occasion and Mr. Watanabe, a fellow speaker, to stay the night with his family.

It was getting dark by the time we arrived in Keisen. Tony telephoned from a booth outside the station, and some minutes later, Mr. Furuno himself came to pick us up in his mini-van. We drove a short distance and stopped in front of a largish but modestly built and modestly furnished bungalow. Mrs. Furuno opened the door and gave us a warm traditional Japanese welcome. We were invited to sit down around the dinner table where all the children came to greet us. Five healthy, suntanned and smiling children, two boys and three girls between the ages of 16 and 8, introduced themselves, then retreated next-door to the kitchen where they were served supper. Grandma and Grandpa were busy with food preparation, and appeared only later to say hello.

The Furunos were a handsome couple in their forties. He, wiry and dark, with a winsome squint and sparkle to his eyes, had the appearance of being both amused and content with life, as he

had every reason to be. He spoke in an even, unhurried manner, with a gentle tone. She was of medium build, lively, good-looking and more openly ebullient about their success. Of course, they did not mean financial success; they meant success of the farming method, which, since its introduction ten years ago, has been spreading all over Southeast Asia. In Japan, about 10 000 farmers had taken it up by 1999; and has also been adopted by farmers in South Korea, Vietnam, The Philippines, Laos, Cambodia, Thailand and Malaysia. Farmers have increased their yield 20 to 50 percent or more in the first year. One farmer in Laos increased his income three-fold. It is obviously a boon to Third World farmers.

"We want to help", the Furunos declared, "financial success is unimportant. We did not patent the method, we just want it to be widely adopted." The method has been researched and perfected over the years in their fields. At this point, Mr. Furuno introduced a young visitor who was working with the family in order to learn the method. "There's always someone here who wants to learn, and everyday, I get several phone calls from people needing advice." He said as a matter of fact, without either false modesty or pride.

The young man's eyes widened considerably when he learned that I was the niece of Mrs. Kyu Ei Kan. Kyu Ei Kan is a writer most renowned for his books on how to make money. And to demonstrate that what he writes is sound, he proceeded to make a lot of money himself. The excited young man pushed the book he was reading in front of me. It had my uncle's photograph on the cover, and the title, *How I Became Rich - An Autobiography*. Mr. Furuno must really be a great success if a young man who dreams of becoming rich should be so eager to learn from him. I made a mental note to tell my aunt, and maybe persuade my rich uncle to go into organic farming business.

"Well, it has been called a 'one-bird revolution'", my host began, "the duck is the key to success." The secret is to release ducklings into the paddy fields soon after the seedlings are planted. But won't the ducklings eat the rice seedlings? No. "It is in their nature not to eat the rice seedlings." Mr. Furuno assured me, then added, "agronomists in the university say it's because rice seedlings have too much silica."

They have made a very good video, complete with English narration, which shows how the ducklings readily take to the paddy field when they are led there to be released. About 20 ducklings are released per tenth of a hectare. They genuinely seem to enjoy getting into the water, where they paddled contentedly between the rows of rice seedlings, now ducking under the surface of the water, now raising their heads to swallow something, but never harming the rice seedlings. In fact, the ducks are good for the rice plants in many ways, including the mechanical stimulation they provide, which make the plant stems thicker and stronger, as demonstrated by careful experimentation.

Mr. Furuno did attend agricultural college, but he did not learn the Aigamo method there. Aigamo is the name for the ducks, which is a crossbreed between domestic and wild ducks. He simply worked out the method by a combination of "contemplation, inspiration and experimentation". Actually, ducks have been raised in paddy fields in China and probably other parts of South East Asia since a long time ago. But the farmers never left the ducks in the fields, and were unaware of all the benefits that the ducks can bring.

The benefits the ducks give to the rice plants are numerous; again, that was worked out by Mr. Furuno's scientific experiments carefully set up in the field. The ducks eat up insect pests and the golden snail, which attack rice plants, they also eat the seeds and seedlings of weeds, using their feet to dig up the weed seedlings, thereby oxygenating the water and encouraging the roots of the rice plants to grow. You can actually see the difference between the plants in the Aigamo plots and the control plots without Aigamo.

The ducks are so good at weeding that farmers who have adopted the method now have time to sit and chat instead of spending up to 240 person-hours per hectare in manual weeding every year

The ducks are so good at weeding that farmers who have adopted the method now have time to sit and chat instead of spending up to 240 person-hours per hectare in manual weeding every year

Besides, 'pests and weeds' have been miraculously transformed into resources for rearing ducks. The ducks are left in the fields 24 hours a day, and do not need to be herded back to the shed. They are protected from dogs by an electric fence or some other barrier around the field. There is a patch of dry land for the ducks to rest and also for them to be fed waste grain from the rice-polishing factory, so they maintain a relationship with the farmer. But otherwise, the ducks are completely free-range until the rice plants form ears of grain in the field. At that point, the ducks have to be rounded up (otherwise they will eat the rice grains). They are then confined in a shed and fed exclusively on waste grain. There, they mature, lay eggs, and get ready for the market.

It was too early in the year to plant the rice seedlings in Furuno's own paddies. Japanese farmers time their planting according to the length of the growing season quite precisely. So, as we came south on the train, we noticed more and more dry vacant fields. Furuno's in-laws, who live some distance away, have already planted the seedlings and flooded the fields, and we were to be taken there to see the ducklings being released the next morning. The father-in-law was once a rich businessman, but had decided to give up business for organic farming. The in-laws, who look ten years younger than their age, live in a large house with a beautiful garden and a permaculture orchard where chickens roam freely to keep the ground free of weeds - another labour-saving invention - and also provide chicken manure to fertilize the trees.

The ducks are not the only inhabitants of the paddy field. The aquatic fern, Azolla, or duckweed, which harbours a blue-green bacterium as symbiont, is also grown on the surface of the water. The azolla is very efficient in fixing nitrogen, attracting insects for the ducks and is also food for the ducks. The plant is very prolific, doubling itself every three days, so it can be harvested for cattle-feed as well. In addition, the plants spread out to cover the surface of the water, providing hiding places for another inhabitant, the roach, and protecting them from the ducks. In fact, the roach grows so well in the paddy that Mr. Furuno has not bothered to count them. What do the fish feed on? They feed on duck faeces, on daphnia and other worms, which in turn feed on the plankton. The fish and ducks provide manure to fertilize the rice plants all through the growing season. The rice plants, in return, provide shelter for the ducks.

Later that evening, we were treated to a delicious meal of home grown organic rice, duck, chicken and vegetables, complete with unlimited bottles of Furuno's own brand of organic sake and fragrant pine wine, both bearing the label, One Bird, Ten Thousand Treasures. Mr. Furuno's one ambition in life is to share these boundless treasures, this unlimited harvest, with the world.

The paddy field with ducks and all is really a complex, well-balanced, self-maintaining, self-propagating ecosystem (see Figure 26.1). The only external input is the small amount of waste grain for the ducks, and the output? A delicious, nutritious harvest of organic rice, duck and roach. It is quite productive. The Furunos' farm is 2 hectares; 1.4 of which are paddy fields, while the rest is devoted to growing organic vegetables. The organic vegetables fields were full of butterflies of all kinds when we visited them the next morning. This small farm yields annually 7 tonnes of rice, 300 ducks, 4000 ducklings, and enough vegetables to supply 100 people. At that rate, no more than 2 percent of the population needs to become farmers in order to feed a nation. Tony Boys indeed believes that with proper management, Japan can become self-sufficient once more. So who needs GM crops? The choice is clear, not only for Japan, but also for all of South

East Asia, and the world at large.

This Aigamo method also explodes the myth that organic farming is necessarily labour intensive. "Organic farming need not be labour intensive, it is fun!" said Mr. Furuno emphatically. The Furunos are not purists, and they use both mechanical harvesters and tractors. Their method is so simple and enjoyable, that five years ago, the two eldest boys managed their own small plot and got a bumper harvest from it. That was also documented on video. Mr. Furuno, however, will complain that they are very, very busy, and no wonder. They run their own vegetable business, process their own ducks and sell those as well. In addition, he writes books, papers, runs courses, and lectures all over Southeast Asia.

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We bathed in the warm glow of this wonderful thought, and ate and drank deep into the night, becoming more convinced by the hour that the harvest is indeed limitless and free to all who work creatively in partnership with her.

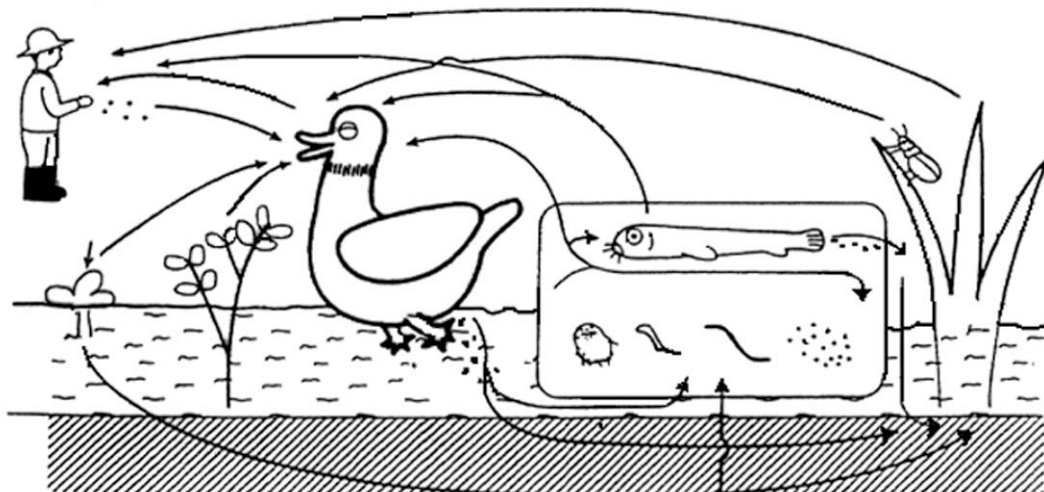
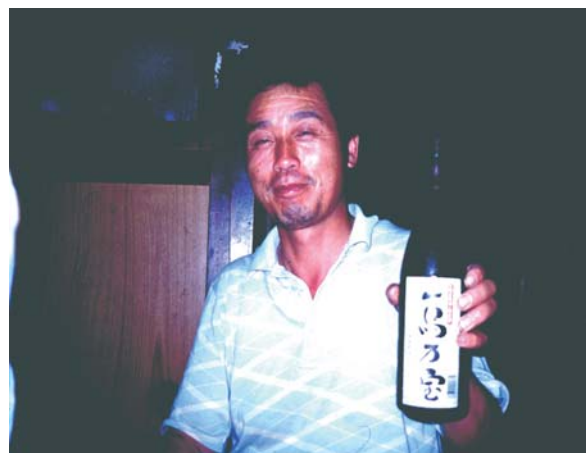


Figure 26.1. The Aigamo system of Takeo Furuno

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Fantastic Rice Yields Fact or Fallacy?

A low-input rice cultivation system invented in Madagascar and spreading all over the world is apparently exposed as without scientific basis, not so; the scientists are ignorant



Rice feeds more than half the world's population, but yields of the crop have been levelling out, and 400 million are said to endure chronic hunger in rice-producing areas of Asia, Africa and South America. According to the United Nations, demand for rice is expected to rise by a further 38 percent within 30 years. To call attention to the problem, 2004 was declared the International Year of Rice. "Rice is on the front line in the fight against world hunger and poverty", said Jacques Diouf, director-general of the UN Food and Agriculture Organisation.

Many farmers all over Asia have already identified low-input, sustainable solutions to the

problem [1].

One simple method that boosts rice yields at much lower cost to farmers originated outside Asia (see Chapter 16). The System of Rice Intensification (SRI) developed in the late 1980s in Madagascar, has since been spreading to other parts in Africa and to Asia. In Madagascar itself, some 100 000 farmers have converted to it by 2004. And more than 20 other countries, from Bangladesh to Thailand, have either adopted SRI, or field tested it, or expressed firm interest. In Cambodia, SRI was unheard of in 2000, but by 2003, nearly 10 000 farmers had converted to it. Advocates of SRI routinely report yields up to

twice or more those achieved by conventional agriculture.

However, eminent agronomists are dismissing those claims as "poor record keeping and unscientific thinking"; and results of field trials, published in March 2004 in the journal *Field Crop Research*, appear to support this view [2].

History of SRI

SRI was developed nearly 20 years ago by Father Henri de Laulanié, a Jesuit priest who worked with farming communities in Madagascar from 1961 until his death in 1995. In conventional rice growing, the plants spend most of the season partially submerged in water. During a 1983 drought, many farmers could not flood their paddy fields, and de Laulanié noticed that the rice plants, in particular, their roots, showed unusually vigorous growth.

From this and other observations, de Laulanié developed the SRI practice: rice seedlings are transplanted quickly when young, spaced widely apart, and most importantly, the rice fields are kept moist but not flooded. In addition, he emphasized using organic compost over chemical fertilizers, so that poor and rich farmers alike could practise SRI [1].

Norman Uphoff, a political scientist and director of the International Institute for Food, Agriculture and Development at Cornell University in Ithaca, New York, stepped into the picture in 1993. He was part of a team trying to find alternatives to the damaging types of slash and burn agriculture that was destroying Madagascar's rainforest. It was clear to Uphoff that if rice yields in the area could be increased from about 2 tonnes per hectare, as it was then, a lot of forest could be saved. He came across de Laulanié's not-for-profit organisation, 'Tefy Saina' meaning "to improve the mind".

Uphoff was looking for a yield of 4 tonnes per hectare, and when he heard them say they could get 5 or more, he did not believe them. But such doubts vanished once farmers in the rainforest regions started using SRI. The results were stunning. "By the end of the second growing season we were getting 8 tonnes per hectare". In 1997, Uphoff began promoting SRI throughout Asia.

Why SRI benefits farmers, consumers and the environment

SRI's benefits lie in important differences from conventional rice growing practice, which, proponents believe, interact synergistically to give high yields [1].

First, seedlings are transplanted at 8-12 days instead of 15 to 30 days after germination, singly as opposed to 2-3 seedlings, and spaced up to 6 times apart compared to traditional practice; for example, up to 50cm x 50cm instead of 20cm x 20cm. This represents a substantial saving on seeds, up to ten-fold or more in some cases. The increased spacing has the effect of encouraging tillers or side shoots to develop quickly, giving many more rice-forming panicles per plant.

Second, the fields are kept moist during all or

most of the growing season instead of being flooded continuously. This tremendous saving on water is particularly important in areas of water scarcity, and avoids the damages of salination that accompanies over-irrigation. It also encourages vigorous root development, which in turn gives more vigorous growth of the rice plants.

Third, no herbicides are used. Weeding is done with or a simple rotary hoe, which returns the weeds to the soil as green manure. This financial saving is offset by increased labour, but labour shortage is seldom a problem for farmers in the Third World, and weeding becomes less arduous in successive years. Giving up herbicides is a health bonus for all concerned: the farm worker most of all, and the consumer; and there is no pollution of the environment and ground water.

Fourth, no mineral fertilizers are used, only liberal application of organic compost. This financial saving is accompanied by an improvement to the quality and fertility of soil, reducing runoff, and improving its water-retaining properties.

Despite its early start in Madagascar, SRI has only begun in other countries since 2000, and already, positive results have been pouring in (see Chapter 16).

Critical scientists

Major critics of SRI include John Sheehy, an agronomist at the International Rice Research Institute (IRRI) in Manila, the Philippines. He said most SRI field studies have appeared in conference proceedings and other publications not subject to peer review.

That is hardly surprising given the lack of interest from mainstream scientists, and its relatively recent uptake in countries other than Madagascar.

In March 2004, Sheehy was lead author of a report on the first trials of SRI carried out by an international team of scientists from IRRI in the Philippines, Sheffield University in the UK, and several universities in China. It appeared under the telling title [2], "Fantastic yields in the system of rice intensification: fact or fallacy?"

This report was written up as a news feature in the top journal *Nature*, under the yet more telling title [3], "Feast or famine?" asking whether SRI was a diversion from "more promising approaches" to increasing yield such as genetic engineering.

Sheehy and colleagues planted a single rice cultivar, shanyou 63, at three experimental stations in Hunan, Guangdong and Jiangsu provinces of China, using SRI and conventional best practice in living-room-sized (8 x 5m) plots in the same fields. Weeds were suppressed with herbicides on the conventional plots but pulled by hand in the SRI plots. SRI plots received extra rapeseed cake fertilizer. Conventional plots were flooded as usual; SRI plots were kept saturated and only flooded 2 weeks before maturity.

Overall, no significant differences were found between the two cropping systems. SRI yielded 8.5 percent higher in Jiangsu, but 8.8 percent worse in Hunan.

Dobermann, the second co-author, was

reportedly "not surprised" [3], as he said every component of SRI had been studied before and found to have little effect. The results also fit Sheehy's theoretical calculation of how much rice a field can produce, an upper limit set by the amount of sunlight falling on it. Based on weather data for Madagascar, Sheehy calculated theoretical maximum outputs for areas that have reported the most impressive yields of 21 tonnes/ha under SRI. By his estimates, the yields are as much as 10 tonnes more than is possible. "You can't get out more than gets put in," he reportedly said.

They concluded that, "SRI has no major role in improving rice production generally".

That was a remarkable sweeping dismissal of the extensive research and trials done by both scientists and farmers on numerous rice varieties in 19 countries over two or more growing seasons. Especially so, when the conclusions are based on the results of limited trials of a single variety for only one growing season.

Riposte

Chinese scientists have experimented with SRI since 2000, and their experience had indicated not all varieties responded to SRI, and that responses tend to improve in successive seasons. Dobermann himself had referred to the possibility of confounding effects when SRI was compared to traditional systems that did not represent the current "best practice". Of course, what is best practice for corporate agriculture is not necessarily best practice for the farmer.

Thus, Sheehy and workers could have stressed the obvious benefits to small farmers, consumers and the environment, even from the results of their own trials. They have obtained the same yields with less than half the seeds in SRI, with no inputs of herbicides, and substantial saving on water.

Uphoff pointed out in a detailed unpublished rebuttal [4], that Sheehy and colleagues have simply not followed the SRI practice in their trials. It did not include the measures recommended for water management and weeding to ensure active soil aeration. Moreover, the high concentrations of chemical fertilizers used with the putative SRI plots (180-240 kg N/ha) would simply have inhibited the soil activity that enhances plant nutrition and growth.

"The merits of SRI methods have been validated by scientists at leading institutions in China, India and Indonesia, the largest rice-producing countries in the world," Uphoff remarked.

Why are scientists in research stations failing to replicate the enormous yield gain with SRI methods obtained by farmers? For example, IRRI started trials with SRI at Los Baños in 2002, and obtained a yield of only 1.44t/ha; and the next season, it was still just 3t/ha. Yet, concurrent SRI trials in the government's Agricultural Training Centre in Mindanao, using three varieties (PSBRc18, 72H and 82) yielded an average of 12t/ha.

When asked by IRRI staff why this discrepancy occurred, Uphoff suggested that IRRI's on-station soils, after decades of monocropping and application of fertilizers, insecticides, fungicides, herbicides etc., might be "almost dead", and hence unable to respond to SRI practices, which depend on increasing the abundance and diversity of soil micro-organisms to enhance plant growth and health.

"The merits of SRI methods have been validated by scientists at leading institutions in China, India and Indonesia, the largest rice-producing countries in the world"

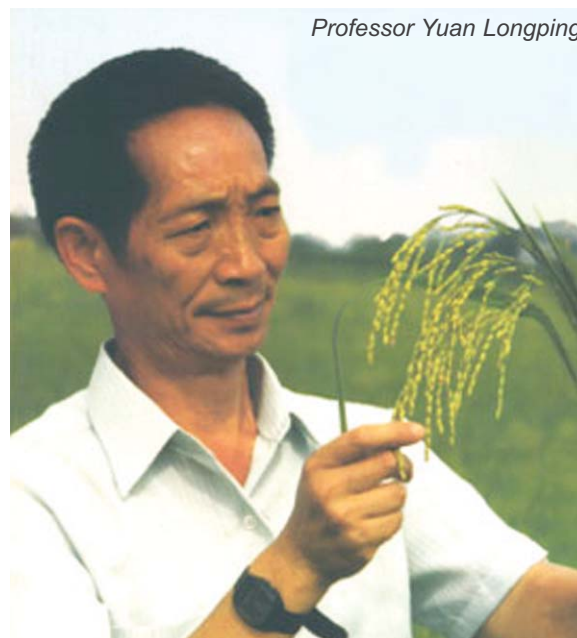
The basis for dismissing the high yields obtained in some parts of Madagascar as "fallacy" is highly questionable. It rests on a 'model' for predicting theoretical maximum yield using 'constants' derived solely from empirical observations on conventionally grown crops, which have no independent justification in terms of the plant's metabolism. For example, biomass accumulation depends on the balance between photosynthesis (which builds up biomass) and respiration (which decreases it), and that can change under different conditions. A healthy plant is also more efficient in using energy and accumulating biomass than an unhealthy one.

An indication that yields more than 20 tonnes/ha may not be "impossible" is that such yields have been recorded for rice growing systems in China in historical times.

Professor Yuan Longping, an expert in breeding high-yielding hybrid rice, who brought SRI to China, stated [5], "According to the estimates of most plant physiologists, rice can use about 5 percent of solar energy through photosynthesis. Even if this figure is discounted by 50 percent, the yield potential of rice would be as high as 22-23 t/ha in temperate regions."

Uphoff maintained [4] that the critics'

An indication that yields more than 20 tonnes/ha may not be "impossible" is that such yields have been recorded for rice growing systems in China in historical times



Professor Yuan Longping



A profusion of deep roots for increasing yield

assumptions are too firmly rooted in conventional practice. Models for estimating maximum yields will not necessarily translate to SRI. "The coefficients for the calculations are based on plants with stunted root systems. SRI plants have extensive root systems," he said.

Nor will single-season trials reveal the full potential of SRI, because over time, better oxygenation leads to the build-up of soil bacteria that interact with the roots and improve the condition of the soil. Even if SRI fails to increase yields when first introduced, as was the case in Thailand, for example, further seasons will see it come into its own.

Proponents insist that SRI is popular because it really increases yields impressively. T.H. Thiyagarajan, dean of the Agricultural College and Research Institute in Killikulam, India, rejects criticisms of individual aspects of SRI. In combination, he says, the whole is greater than the sum of its parts. "The synergistic effect of all these components is the crucial thing." He helped convince the Tamil Nadu state government to spend US\$50 000 to promote SRI to local farmers.

In fact, the individual components have been tested in Madagascar and other countries, and each component was found to increase yield. The one that appeared to give the most increase was transplanting younger seedlings. But this practice is more challenging for inexperienced farmers used to handling sturdier older seedlings.

New evidence

Uphoff's weighty response [4] drew attention to new evidence from scientists in China, Indonesia and India. SRI evaluations were started in Tamil Nadu Agricultural University in India in 2001, and by 2003, it had demonstrated such improvements in yield and profitability that the state government provided \$50 000 for spreading SRI practice. About half the rice crop in the Cauvery Delta, the main rice-producing area of Tamil Nadu, would be given over to SRI cultivation; the farmers are so impressed with the size of the harvest and cost

savings, including water, over the past two years.

Sheehy and colleagues reported that SRI crops took two weeks longer to mature, but that was most likely due to the soil not being well drained and aerated. When properly managed, crops mature more quickly under SRI. In Andhra Pradesh SRI crops matured 10 days earlier, while in Cambodia, they ripened about one week before the conventional crops.

The claim that SRI gave no advantage compared with "best practice" or officially recommended improved cultivation methods was also refuted. In Nepal, farmers compared SRI with their own usual practices and 'improved' practice. In 2002, the average SRI yield of 8.07 t/ha was 37 percent higher than the average with improved practices, and 85 percent higher than the average with farmers' practices.

Response from India

A powerful response to *Nature's* news feature came from geneticist A. Satyanarayana, Director of Extension at the State University of Andhra Pradesh in Hyderabad, who was responsible for introducing SRI to Andhra Pradesh [6].

He learned about SRI on a study tour to Sri Lanka, and was amazed to see the potential of this system. On returning to Andhra Pradesh, he started educating farmers on the skills involved in SRI and motivated them to take up this system on a small scale in demonstration plots. They planned to organise 50 demonstrations through the extension service and 150 through the State Department of Agriculture, but more than 300 farmers took up SRI during the summer season of 2003.

On average, the size of the demonstration plot was 0.4 ha, with the largest at 1.6ha. The trial included as many as 10 different varieties, chosen by the farmers themselves, were tried in all 22 districts of the state, and tested under different soil and irrigation systems. The results indicated an average yield advantage of over 2.0 t/ha. About 40 farmers got yields over 10 t/ha, and 5 districts had average yields over 10 t/ha. The highest recorded was 16.2 t/ha followed by 15.7 t/ha. The average over all the demonstration plots was 8.36 t/ha compared to 4.9 t/ha with conventional practice, and the state average of 3.89 t/ha. These yields were not theoretical. They were properly recorded after thorough drying.

On seeing the performance of the SRI system, many farmers volunteered to practice SRI during the 2004 winter season on more than 5 000 acres in the state.

Many farmers used SRI on over 10 acres. One farmer (Mr. N. V. R. K. Raju) practiced SRI on over 100 acres (40ha.), and an average yield of more than 10 t/ha was expected.

"I request sceptics to visit Andhra Pradesh and see SRI in practice before drawing conclusions." Satyanarayana said [7].

Under SRI, the rice crop was maturing 10 days earlier than with usual cultivation practices, irrespective of the variety, which was contrary to what was stated in the *Nature* news feature. Also, SRI required less water and less

chemical inputs, and gave higher grain as well as straw yield. Moreover, the SRI rice crop had withstood cyclonic gales and a cold spell.

The SRI results are not "miracle", Satyanarayana said, but quite explainable. Planting young seedlings carefully and at wider spacing gives the plant more time and space for tillering and root growth. Careful water management, keeping the field wet and not flooded gives better yield because it supports healthy root growth. "This practice should be encouraged everywhere as the whole world is facing water shortages." Weeding rice fields with a rotary weeder helps by churning the soil and incorporating the weed biomass as it aerates the root zone. This encourages the soil microorganisms to proliferate and makes the soil living and healthy.

Satyanarayana pointed out that rice yields all over the world have levelled out under the flooded Green Revolution cultivation. Genotype-environment interactions are known to affect the plants' phenotype and performance, and we need to be looking for alternatives to the present costly practices.

And indeed he was right as farmers around the world continued to benefit from SRI while IRRI scientists remained sceptical and are left behind (see Chapter 16).

Reductionist conventional approach needs to be balanced

A published riposte [8] from Willem Stoop, a consultant in tropical agriculture in the Netherlands, and Amir Kassam at the CGIAR Science Council in Rome, Italy, reinforced the criticisms levelled at the IRRI scientists. They pointed out that intensively used fields in experimental stations have received sizeable applications of agrochemicals year after year; and it is known to take a long time to regenerate such soils. That may be the main

Intensively used fields in experimental stations have received sizeable applications of agrochemicals year after year; and it is known to take a long time to regenerate such soils. That may be the main reason why short-term experiments carried out at IRRI and other research stations are not comparable to those in farmers' fields

reason why short-term experiments carried out at IRRI and other research stations are not comparable to those in farmers' fields. Stoop and Kassam are critical of modelling exercises purporting to show that the highest SRI yields are physiologically impossible, as the models concentrate on some above-ground processes, ignoring the rest of the plant below ground and the soil.

The SRI debate, they said, presents a clear example of a long-term controversy based on two contrasting research philosophies: "an integral versus a reductionist view. The first is relatively "open" to surprises of incompletely or unexplored domains and the opportunities created by essentially incomplete knowledge: the second is much more dogmatic and clings to established knowledge and principles, while missing out on livelihood aspects." They are convinced that we need both, "Without such balance, research may become reduced to a costly, number-crunching "robotic" exercise." I cannot agree more.

They also questioned the motives of scientists critical of SRI, suggesting that short-term interests and/or the credibility of certain research institutions may be at stake.



Wider spacing for increasing yield

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Saving the World with Biodynamic Farming

The importance of marginal farmers in India using an emergent agricultural knowledge system against the corporate takeover of farms



A farm family in India

One farmer, one cow, one planet

What if the world were an apple? One quarter of the apple is land and the rest is water. Cut the land in half and put aside that which is deserts and mountains. Quarter what is left and the peel of one of those quarters represents the topsoil that must feed the whole world. This analogy illustrates how important it is to get the best out of the available soil to provide abundant and nutritious food for everyone on the planet [1].

Peter Proctor is a soil scientist who has worked with the stuff for over sixty years [2]. His favourite invertebrate is the earthworm, which he describes as "the unpaid servant of soil health" and his favourite animal is the cow because of all the dung it provides. Dung is something that Proctor prizes more highly than gold, jewels, fossil fuels, or many other natural resources. His recommendation for green-fingered gardeners and for the long term sustainability and security of global agricultural systems is the same: a complex preparation of medicinal plant material (see Box) added to compost, manure and slurry. The mineral enriched

compost preparations lessen soil compaction, enhance the quality of topsoil, increase microbial activity and encourage earthworms.

Known as the father of the modern biodynamic farming movement in New Zealand, Proctor's work with crisis-struck farmers in India (see Chapter 23 [3]) over the past fifteen year provides a strong grassroots alternative to industrialised conventional agriculture, which is failing on all counts (see Chapter 2 [4]) Like many other critics, he believes that we have become separated from our food by a global system of multinational corporations controlling what we grow and what we eat, and biodynamic agriculture may be the last chance this planet has for a healthy, secure, and ecologically efficient food supply.

What is biodynamic agriculture?

Biodynamic agriculture is an advanced form of organic agriculture with an emphasis on food quality and soil health [5]; and as such, uses no synthetic fertilizers or pesticides. 'Biodynamic' originates from two Greek words, bios meaning

life, and dynamos meaning energy. The pioneer of biodynamic agriculture was Rudolf Steiner (1861-1925) an Austrian scientist, philosopher, and educator. He identified the deleterious effects on the soil and the deterioration of the health and quality of crops and livestock that farmers experienced following the introduction of chemical fertilizers at the turn of the twentieth century. In a series of eight lectures known as the "Agricultural Course" made in 1924 [6] Steiner taught the fundamental ecological principle that the farm is a living organism, an individual self-contained entity within a whole harmonious system. (This is similar to the idea that a sustainable system is like an organism [7], which will be put into practice in an integrated food and energy 'Dream Farm 2 see Chapter 34 [8]). In 1928, the first ecological label "Demeter" was used to certify the high quality nutritional food produced by organic and biodynamic agriculture. Since then biodynamic farming has developed to be one of the most sustainable and successful forms of organic agriculture practiced in forty countries across the world [9].

A biodynamic farm is characterized by self-sufficiency and biological diversity where crops and livestock are integrated, nutrients are recycled, and the health of the soil, the crops and animals, and the farmer too, are maintained holistically. The strength and resistance to disease of the whole system is crucial, so genetically modified organisms (GMOs), which originate from forcing bits of DNA including those from viruses and bacteria into plant cells are excluded altogether. Instead indigenous seed varieties and breeds best suited to the natural conditions (bedrock, soil, weather, flora and fauna, insects, birds and human populations) are developed for the specific locality and further distances too. Biodynamic systems weave together natural plant, animal and mineral resources within environmental limits to enhance the quality of soil and crop production and bring about ecological balance. Consideration of the farm as an ecosystem feeds into holistic management practices that embrace the environmental, social and economic aspects of the farm.

Its objectives differ significantly from those of conventional agriculture, or agribusiness, which maximizes profit with mechanical and technological inputs for unlimited exploitation of the earth's resources. The biodynamic model feeds family and farm workers first, and then trade surpluses to the local community. A central belief is that specific natural substances are carriers of forces that create life (see Box), and that celestial rhythms, primarily the phases of the moon, directly affect terrestrial life. One main difference between organic and biodynamic farms is that organic farms often exclude animals for ethical reasons and monocrop production is common.

Why a biodynamic farming revolution?

Biodynamic farms have broad ecological implications as a blueprint for agriculture when fossil fuels are scarce (see ISIS report Which Energy?[10]). But they have cultural implications

too. Today in India, biodynamic and organic farming methods represent a revolution, one farmer at a time, against the vested interests of agribusiness disguised as science and the global dominance of corporations such as Monsanto.

According to Afsar Jafri of Focus on the Global South in Mumbai, the advantage of biodynamic farming for Indian farmers is that they are practising a form of non-chemical, non-toxic farming that does not require the use of any hybrid or GM seeds. He says [1], "Monsanto is a company that monopolises and its only objective is that every farmer in the world who buys seed buys from Monsanto." And, as 60 percent of India's population depend on small and marginal farming, the impact of stopping traditional methods of seed saving and swapping, and taking farmers to court for patent infringement where they are fined 1-2 million rupees, is literally killing them. Jafri explains that Indian farmers want freedom and independence from corporate control. "We don't want any Monsanto or Syngenta to tell us what seed we grow and what crop we should harvest and what food to eat" he says. This perspective reflects Ghandi's definition of food sovereignty [11] or the right of all people to decide what they grow and eat free of international market forces (see also Chapter 2 [4])

What are biodynamic preparations?

The methodology of biodynamic compost preparations in a contemporary setting is not "voodoo doo-doo", or "muck and magic" as detractors have cursorily labelled it, but instead a scientific combination of six medicinal plant extracts and two field preparations (see Box). Dr John Reganold is the Regents Professor of Soil Science at Washington State University. He says that people may think biodynamic agriculture is strange because of the preparations, but they are so different it would be hard for anyone other than Steiner to come up with them [1]. The biodynamic preparations (BD) consist of recycled mineral, plant or animal manure extracts that are fermented over time and added in homeopathic or very dilute quantities, to compost piles, manure and slurry, which are then applied to the soil or sprayed directly onto plants (see Box 28.1). The specific properties of the medicinal compounds such as calcium (Ca), silica (SiO₂) and iron (Fe) regulate the decomposing and humus-forming processes in the soil and provide the rich base needed for healthy plant growth.

Without humus, soil is lifeless and lacks the three major nutrients, nitrogen (N), phosphorus (P) and potassium (K) that plants need to thrive. As P and K are not present in the air, they are biodynamically "farmed" into the soil by enriching compost with the BD preparations. Thus nourished soil strengthens plant roots and generally produces nutrient rich crops not deficient in trace elements such as selenium (Se) and zinc (Zn). Reganold's own studies demonstrate that soils treated with organic or biodynamic compost have a greater capacity to support soil microorganism activity than soils managed with mineral fertilizers and pesticides [12]. One study showed that BD

preparations are effective in homeopathic quantities and significantly affect compost development by raising the temperature slightly higher to 3.5 degrees over the first eight weeks [13]. Another study that paired sixteen conventional farms with biodynamic farms found that biodynamic farms have better soils and are more profitable [14].

Biodynamic compost piles are known as "windrows" and can be up to 2ft high and 12 feet long. Windrows are built upon alternating layers of brown organic matter such as dead leaves which provides carbon and green plant matter that provides N. The BD preparations 502-507 (see Fig 28.1) are placed 5-7 feet apart in strategically placed holes at around 20 inches deep in the pile. BD preparation 507 or liquid valerian is poured into one hole and applied all over the outside by spraying, or hand watering. The windrow is then scattered with a few handfuls of soil, covered with straw and left to decompose for six months to one year. Organic residues break down into smaller particles and are then re-synthesised into complex humic substances. Research shows that low tech methods of composting are just as effective as mechanized methods at stabilizing nutrients and humus [15].

Biodynamic preparations threatened in Europe

The use of buried animal parts to make BD preparations (see Box) has always been controversial. Peter Proctor explains that cow horns retain some of the enzymes from the animal's digestive system that act as a catalyst to further aid compost fermentation [1]. However,

Dandelion (506)	Yarrow (502)
Nettle (504)	Oak Bark (505)
Valerian (507)	Chamomile (503)

Fig.28.1 The medicinal BD preparations arranged in a windrow

biodynamic farmers in Europe are facing a challenge from European Union Regulation 1774/2002 that prohibits the burial of any parts of fallen livestock on farms [16], despite no cases of BSE ever being found on biodynamic, or "Demeter" certified farms anywhere in the world. In contrast, outbreaks of animal disease such as BSE, Foot and Mouth and now, Avian Flu and Blue Tongue are ever-present threats in conventional intensive farming systems. In the UK in 2001, 594 000 cattle and 3 334 000 sheep were culled in an outbreak of Foot and Mouth, which cost the taxpayer £3 800 million [17]. This clearly calls into question the economic and environmental sustainability of conventional industrial farming

Organic farms work at village level

During the past fifteen years, Peter Proctor has visited India twenty five times to teach biodynamic farming methods to as many farmers as possible. Despite his eighty years, he visits ten villages a day. Proctor's involvement is part of a major campaign to promote and encourage alternative forms of agriculture that use no synthetic inputs in response to an epidemic of farmer suicides, most of whom were farming GM crops [1]. This initiative has encouraged 10 000 biodynamic compost piles, 4 million hectares under organic farming methods and 1 000 officially supported training schemes for biodynamic and organic farms in the Maharastra region, a suicide hotspot. These farms work at village level and each village has formed an organic federation accredited at district level where farmers participate to solve their own problems. By building up their knowledge base, farmers gain independence from agribusinesses through reducing external inputs. By using biological practices such as green manures, cover cropping, companion planting, and natural insecticides, money is saved that would have been spent on costly pesticides and fertilizers, and is put back

Box 28.1

The six medicinal plants used in biodynamic compost preparations - 502-508

- 502 Yarrow flowers (*Archillea Millefolium*) are connected to the potassium and sulphur processes and helps to draw in beneficial substances to replenish soil growth tired from many years of cultivation.
- 503 Chamomile flowers (*Matricaria recutita*) are connected with the living calcium processes that stabilise plant nutrients, dampens down excessive fermentations and improves growth.
- 504 Stinging Nettle (*Urtica dioica*) the whole plant has a relationship to iron and helps to stabilise nitrogen.
- 505 Oak Bark (*Quercus robur*) is calcium rich and helps to ward off diseases and fungal attacks.
- 506 Dandelion flowers (*Taraxacum officinale*) are connected with the living silica processes activating influences in the soil and enabling the effective interrelationships of nature.
- 507 Valerian flowers (*Valeriana officinalis*) have a strong affinity to the activity of phosphorus. They are extracted into water and sprayed over the entire compost surface
- 508 Horsetail (*Equisetum arvense*) all parts of plant used dilute as a foliar spray fungicide for plant leaves. One level teaspoon of each preparation is added to a seven to ten tonne compost pile.

The two used in biodynamic field preparations - 500-501

- 500 (horn manure) is BD enriched cow manure packed inside a female cow horn and buried in the ground 40-60cm deep in autumn. In spring the fermented compost is ready to be dug up and diluted in homeopathic quantities (one teaspoon to 40-60 litres of water) then stirred for an hour in clockwise and anticlockwise directions every other minute before being applied directly onto the soil. The 'dynamizations', or stirring, creates a vortex that imbues the biological compounds and the water with the fundamental principle of plant life, "Order arising out of chaos" [1]. One cow horn used dilute for 1 hectare of land.
- 501 (horn silica) is powdered quartz packed inside a female cow horn and buried for six months through spring and summer. A dilute preparation is then applied as a foliar spray to stimulate and regulate plant growth. One cow horn used dilute for 25 hectares of land.

into their own communities to improve the quality of life of everyone. This great change in rural prosperity has brought whole communities back together again and enabled the integration of health education and family planning in local settings.

The good news about the benefits of biodynamic farming has spread quickly and there are now in excess of 200 000 compost piles throughout India that recycles cow dung, paddy straw and almost anything else nature provides. For example, one biodynamic farmer persuaded his local council to let him use the tonnes of fallen leaves collected from around the village that would otherwise have been burnt to construct impressively large windrows on his farm. Recycling local and freely available resources such as leaves and dung from the ubiquitous and revered cows provides an appropriate alternative technological strategy for Indian farmers and doesn't cost lives.

Alternatives to the "Green Revolution"

How to Save the World [1] is an award winning independent film that documents the progress of Peter Proctor and the biodynamic farming movement in India. Writer and director Barbara Burstyn treats us to visions of verdant biodynamic farms where colourfully dressed young men and women prepare the BD field preparations and spray them in spiral motions from large copper bowls onto the soil. The old ploughman driving two golden cows tells his story of how the soil has become soft and almost butter-like and alive with worms under biodynamic systems. Elsewhere, we see vast areas of land where the soil is so saturated with layer upon layer of chemicals that it has become great lumps of dry, dusty boulders where no life exists. Organic farmer Jaspal Singh explains that this is the result of the "Green Revolution", - of which his own father was a pioneer - that has not only been a killer of farmers, but has made the soil unproductive, waterlogged, pest infested, depleted of nutrients, and has dried up rivers. Singh says that until he learned about chemical free organic and biodynamic farming systems that uses fifty percent less water, he had no alternative to the chemical and water intensive practices of the Green Revolution.

Globalisation lacks social responsibility

Despite the negative effects of chemicals on the soil the use of pesticides is increasing and claims the lives of at least 200 000 people per year (see Chapter 21 [18]) In many cases this increase is taking place as yields of staple crops are decreasing (see Chapters 9, 10 [19].)

In India, seed dealers get huge commission from chemical companies and Indian farmers are forced to take hybrid seeds and pesticides as part of credit packages from salesmen in order to continue to farm. Shantytowns of farmers evicted from their lands because of failed harvests and unpaid debts have sprung up by the rows of pesticide sellers set up in small roadside huts with

shelves heaving with packets of GM seeds and tins cans of pesticides. These seeds cost farmers four hundred percent more and yield thirty percent less. A 2006 report shows that 60 percent of farmers using GM seed could not cover their investment, let alone feed their families [20].

How to Save the World captures the rhythmical movement and vitality of India, but cannot resist a cynical take on the corporate model that builds a market by forcing once independent farmers into debt and dependence on international aid for the very same grains and legumes they once grew successfully. It puts the blame for dependency and for world hunger fairly and squarely on the shoulders of industrial agriculture, genetic engineering, military dominance and trade liberalization, and not on food scarcity [1]. The failure of the globalised free market is starkly symbolized by miles of empty toll roads, built as an infrastructure for corporate agriculture that many farmers in India cannot afford, or do not want.

A model fit for the future of farming

On the positive side, we are presented with an alternative model to globalisation. The new paradigm is represented by bioRE [21] an organic cotton project started in 1991, which is also an agricultural training centre committed to the development of organic and biodynamic cotton farmers in the Madhya Pradesh and Maharashtra regions of India. It enables farmers to construct biogas facilities (see also Chapter 33 [22]), water tanks and windrows to keep the soil healthy and pesticide-free so they can farm for a long time to come. Farmers are relieved of financial insecurity because bioRE covers them not only for loss of crops, but also for the transition year to becoming organic, or biodynamic farmers. As a textile chain they purchase cotton harvests at ten percent above the market price over a five year fixed contract. This tackles head on the problems of economic globalisation that leave farmers at the mercy of corporations bent on maximising short-term profits. Not only do farmers get a fair price for their cotton, but they no longer have to buy the expensive packages of seeds and pesticides that have led them into debt and suicide. The alternative model directly links the farmer to the consumer through traceable supplies and represents moral, social, ethical and environmental responsibility towards everyone along the chain with satisfying outcomes for all.

How to Save The World leaves us in no doubt that one would be fortunate to find oneself

connected to an idyllic rural biodynamic farm where pay and conditions for workers and their families are fair, food is of the highest quality and plentiful, the local economy thrives, the farm shop is a sell out, and the farmer and the local community is happy and content. All the more exciting, as there is no reason why millions more small to medium sized farming communities everywhere could not enjoy the same good life.

For a copy of *How to Save the World*:

<http://howtosavetheworld.co.nz/>

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Food for Thought

A small, diverse and self-sufficient farm in Britain that means to set an example for the rest of the country



Brian with mangolds for livestock fodder

"I could see the haulms [above ground parts] of the potato crop turning black as they sprayed the acid on it!" Brian Baxter waved his arm towards huge undulating fields, typical of the intensive crop farming practised all over this part of Norfolk, about 150 miles north of London. The neighbouring 300-acre field had been sprayed with sulphuric acid to kill off a small patch of potato blight.

Brian and his wife Jo bought their adjacent two-acre plot near Swaffham in Norfolk in the 1960s. After four kids, eight grandchildren, hard

work and the gradual acquisition of another 20 acres, they now maintain a small farm for the purpose of feeding themselves and their family. Immense satisfaction is evident on the couple's faces as they tell us about their near forty years of self-sufficiency, but so is concern at the destruction of habitats and soil that they feel the industrialised farms all around them have contributed to.

Brian and Jo have tried their hand, and by all evidence have become proficient, at many different skills around the farm. After deciding that

she didn't want to lose the fleece of their sheep in payment to the local shearer, Jo borrowed library books and taught herself to spin wool. Their 19th century renovated railway workers' cottage is now dotted with weaving looms draped with half finished scarves and tablecloths.

"We hardly sell anything, we grow everything for ourselves and our family," said Brian as we walked past a long shed with small farm machinery, composting barrels, onions drying, and an assortment of various tools and implements used around the farm.

Brian approached a composting barrel and poured some thick black liquid into an old saucepan.

"This is our comfrey juice," said Brian as he holds up the saucepan for us to sniff its rather pungent odour. The 'juice' is created from comfrey leaves compressed with a little water added, the end result is an excellent natural fertiliser. The comfrey leaves are also fed to their chickens, which ate them with gusto!

The couple have grown comfrey for many years and are amazed that so few gardeners and allotment holders grow it, as it has many uses. This herbaceous perennial grows year after year, and is purported to have healing properties for a great many ailments. Jo herself has used it successfully in treating her horses, and its wound-healing properties are also evident in their sprightly dog Flicka, whose broken leg was healed with the aid of a comfrey poultice and their veterinarian daughter.

On a plot of about a third of an acre, Brian grew fodder beet and mangolds as food for his sheep, cattle, horses and llamas (kept for their wool), as well as a potato crop.

Brian contacted ISIS a short while ago after reading the articles on the system of rice intensification (SRI) techniques developed in Madagascar (see Chapters 16 and 27) and invited us to visit his farm. He too claims to have increased his potato yield substantially by turning conventional seed planting ideas on their head.

After being regularly disappointed with his potato yield for several years, Brian adopted a new system of planting his seed potatoes, which also involves spacing the plants farther apart. Instead of drilling a hole, and spacing each seed potato 15 to 18 inches apart in each direction, he now uses a sub-soiler. The sub-soiler lifts the earth as it cuts through the soil at a depth of 18 to 24 inches. As the main blade churns the earth below the surface, the shaft cuts channels, which are located six feet apart. The seed potatoes are then placed into this channel or row at 18-inch intervals. This method of spacing the plants further apart allows air currents to flow freely around the plants, preventing disease.

Brian claimed that his potato yield has been transformed, and he is convinced that this system is far more effective than conventional ways of planting potatoes. He tells us that he gets more weight per potato; for the same weight, his bags are now only two-thirds full. Recently dug potatoes showed all the signs of a strong yield per plant and there was not a bad quality spud anywhere.

His concerns go far beyond a desire to increase his own potato yield. Brian believes everybody with a garden or allotment has a responsibility to use that to grow a portion, if not all, of their own food. In addition to the vegetables and other crops, and the usual animals for meat, milk, eggs and wool, Brian and Jo also have turkeys, and a pond with carp and ducks.



After being regularly disappointed with his potato yield for several years, Brian adopted a new system of planting his seed potatoes, which involves spacing the plants farther apart. He gets more weight per potato; for the same weight, his bags are now only two-thirds full

Over forty years, Brian and Jo have witnessed the intensification of large scale farming all around them. They have seen increasing amounts of pesticides and herbicides being used, with no evidence that this has actually improved crop yield. Brian said that farmers he has met complains of needing increasingly more powerful equipment to plough the compacted soil of their fields. They also tell him that the earth is now so barren of life that birds no longer feed from the freshly ploughed soil. Brian is convinced that current farming methods are unsustainable. As for GM, it's just taking the intensification one step further, with possibly even worse consequences.

His message is clear; we all need to reduce our reliance on intensive agriculture, and produce food locally and in a sustainable manner.

"People think organic farming is a new thing," he said, "but this is how it always used to be done. Everybody with a small patch of land needs to be doing something."

Brian and Jo have discussed the idea of introducing an Internet website for small gardeners and allotment holders to share knowledge and ideas of growing food sustainably. This could be the start in catalysing action to ensure food production at a local level, which does not harm the environment; the alternative is unacceptable, they feel.

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Multiple Uses of Forests

A global trend away from monoculture tree plantations towards multiple uses of native forests is good for conserving forest ecosystems, but progress is hampered by a dominant paradigm that treats forests like cornfields



All commercial forests should be managed for multiple-use

Erkki Lähde, Finland's foremost forestry scientist, is convinced that forests can no longer be divided into those focussing on timber production and others with multiple uses. Instead, all commercial forests, in Finland and elsewhere on our planet, should be treated with their multiple uses in mind, in order to sustain their ecology and biodiversity in a 'close-to-nature' state. Merely safeguarding the productivity of timber and pulp - in monoculture plantations - while preserving 'key biotopes' in their natural state is no longer considered sufficient for species conservation.

The emphasis on multiple uses of commercial forests is particularly important for many indigenous peoples who have been an integral part of forest ecosystems for millennia; whose livelihoods are being threatened by deforestation, which includes replacing native forests with monoculture tree plantations, particularly now, under pressure for producing biofuels (see Chapter 5).

Monoculture tree plantations are anathema to the biodiverse native forest ecosystems of the world. The United Nations Environment Programme (UNEP) estimated that about 60 percent, and possibly closer to 90 percent of all

living species are found in tropical forests [1]. Thus, adopting multiple uses of forests that can sustain their biodiversity is extremely significant for conserving the earth's species; and there has been a growing trend towards doing just that, though not quite fast enough.

Recent research in Mexico also shows that cacao and coffee-based agroforestry systems managed with low inputs by small holders harbour significant biodiversity compared to the monoculture plantations [2].

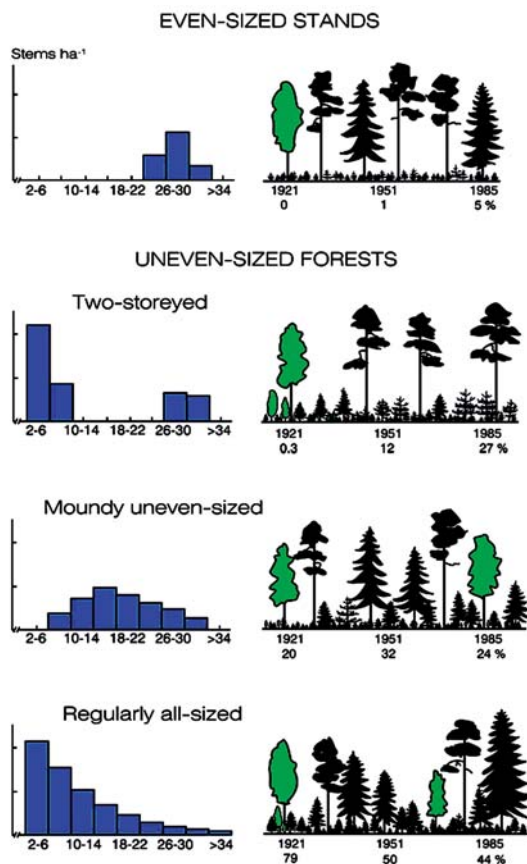


Fig 30.1. Different distributions of tree sizes and their percentage occurrence in natural or mature forests in three surveys carried out in 1921, 1951 and 1985.

The prevailing paradigm that treats natural forests like cornfields

One major obstacle to adopting multiple uses of forests is the lack of a good model of the natural forest ecosystem. "The prevailing paradigm still treats natural forests as if they are cornfields," says Lähde, "The entire stand is supposed to be destroyed at certain intervals by natural disturbances such as forest fires or storms. After that a new forest would grow from the saplings."

Based on that model, thinning and clear-cutting forests are routinely carried out to this day. The smallest and youngest trees and the under storey are cleared away, leaving uniform trees standing like "rows of carrots"; and when the trees are ready for harvesting, they are clear-cut, and the stock replaced. This is said to 'mimic' nature. More accurately, it is supposed that natural forests imitate their cultivated counterparts, producing stands of trees that are uniform in size or age.

However, when real forests are examined, they tell a very different tale; there are no uniform or

even stands of trees. Instead, native forests - especially mature and long established forests - tend to have diverse, uneven-sized mixed stands.

Forest trees come in all sizes

Finland was the first country in the world to carry out a national forest inventory as early as the beginning of the 1920s. The inventories have since been repeated once every decade. Measuring tree diameter at breast height has been one of the ways to investigate forest stand structure. It fell to the lot of Lähde and his research team to carry out the ninth inventory in the early 1990s; and for the first time since inventory began in Finland, the distribution of stem diameters of the trees was published.

Lähde went through the old inventory data for advanced and mature forests in Southern Finland for 1920s, 1950s and 1985. He found four possible distributions in the data: even or uniform sized, two-storeyed, "moundy uneven-sized" (normal distribution), and "regularly all-size" (see Fig. 30.1). The vast majority of advanced and mature forests had the "regularly all-size" distribution. This was also true of data from the Swedish National Forest Inventory.

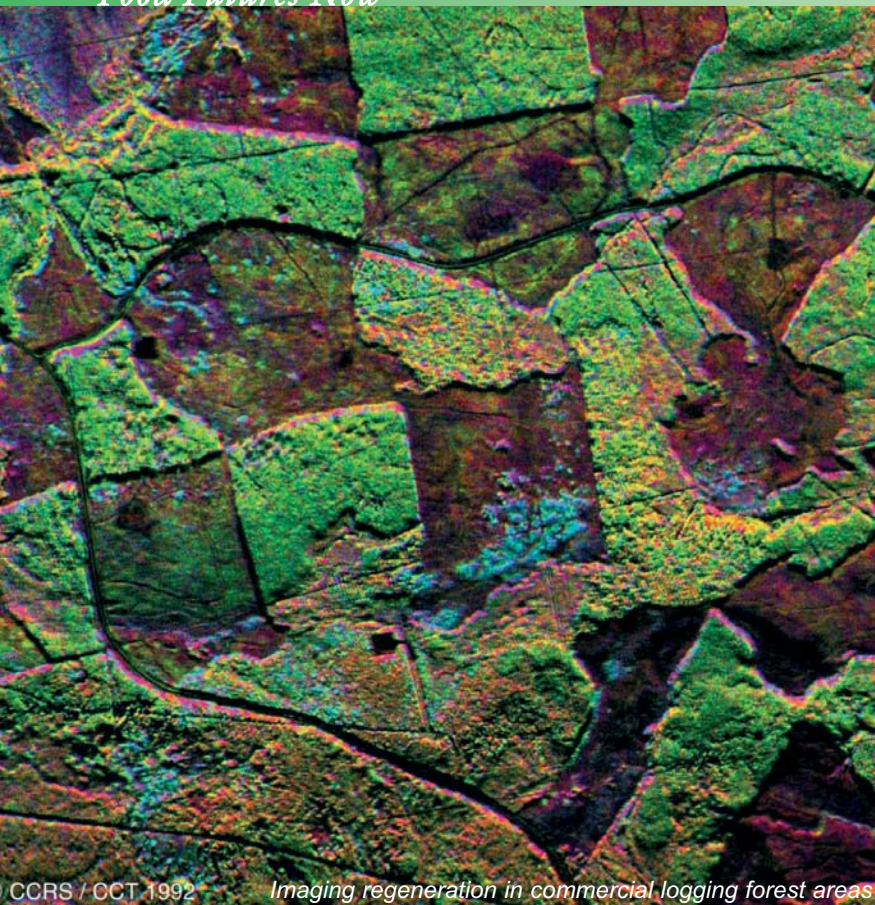
Biological significance of the "all size" distribution

The "regularly all-sized" distribution discovered by Lähde and colleagues for the stem diameter of forest trees is commonly referred to as the $1/f$ distribution, where f is the frequency of the size class. It says that the frequency of the size class varies inversely as the diameter: the bigger the trees, the less frequently they occur. The $1/f$ distribution is possibly the most significant 'law' discovered within the past 15 years for natural processes ranging from earthquakes and avalanches to the branching of trees; and is especially relevant for biology [3]. This distribution is characteristic of fractals - such as coastlines and trees - which have fractional dimensions between the usual 1, 2 or 3; as well as the same or similar structure over many scales.

I have suggested that the "regular all size" or fractal distribution applies to the totality of species in an ecosystem, which enables the ecosystem to maximize energy capture and storage and minimize dissipation. Translated into biological terms, it would predict an increase in biodiversity and productivity [4, 5]. Sure enough, there is evidence for that in forest ecosystems. The "regular all size" distribution supports more biodiversity of trees and higher productivity, and any measure that destroys that fractal structure diminishes both.

Lähde and his colleagues calculated the diversity index of trees in forests with the four different distributions: the even sized stands scored 7, the two-storeyed stands scored 15, the "moundy", 21.5, and "regular all-sized", a clear winner at 39.5 [6-10].

Researchers in the Canadian Forest Service in the forests of North Central British Columbia had



CCRS / CCT, 1992 *Imaging regeneration in commercial logging forest areas*

previously shown that the impact on biodiversity was dependent on the method of harvesting, with single-tree selection and group selection causing the minimum damage (see Box 30.1) [11].

Treatment	Diversity (%)
Untreated	100
Single-tree selection	90
Group selection	80
Shelterwood cutting	55
Remodelled clear-cutting	24
Seedtree cutting	20
Clear cutting	5

Box 30.1. Harvesting method and diversity

Lähde and colleagues compared the productivity of even-sized stands with uneven-sized stands in experimental plots in

Stand/developmental stage	Volume m ³	
	CAI*	m ³
Clear cut area	0	0.0
Regeneration area with seed trees	28	0.8
Regeneration area with sapling stand	26	2.7
Young thinning stand	140	5.1
Advanced thinning stand	78	5.1
Mature stand	180	4.4
Regularly all sized stand	194	5.9

*Current Annual Increase

Box 30.2. Productivity of even-sized and uneven-sized stands

southern Finland.

The results (Box 30.2) [7, 9] showed that clear cutting leads to unstable wood production. During regeneration and sapling stages, growth remains low, reaching its peak only when maturing. At maximum, it is still lower than the average production of regularly all-sized stands. Thus, the latter are more productive and more profitable on average than even-sized stands. The quality of the wood produced is better and it is able to sustain multiple uses on account of its higher diversity.

In the short-term, clear-cutting is a cheap and technically easy option, and hence "an obvious favourite of the forest industry" which enjoys the full benefits while leaving forest owners to bear the costs of long and often expensive process of regeneration. "Then, not only the timber production is at its minimum but the multiple use and sales values of the forest are also at the lowest." Furthermore, the risk of failure remains high throughout the regeneration process.

Somewhat surprisingly, low thinning of small trees - a common practice in forestry carried out in the belief that it favours the growth of large trees by removing "competition" - also reduces wood productivity (see Table 2). And this was confirmed in another set of experiments involving 23 Norway spruce-dominated experimental stands extending from southern to northern Finland, where Lähde and coworkers found that CAI averaged 5.4 m³ha⁻¹ in single-tree selection plots compared with 4.6 m³ha⁻¹ in low thinning plots.

The reason why single-tree selection favours wood growth, they suggest, may be because removing slow-growing dominant trees releases space and nutrients to enable small trees to grow more rapidly; while removing small trees in low thinning results in little or no benefit for the remaining dominants.

Tree plantations do not make economic sense

In order to counter the market-driven economic arguments all too often used to justify the destruction of our natural resources, there have been valiant attempts to estimate the value of 'ecosystem goods and services' in monetary terms.

An international team of conservationists led by Andrew Balmford in Cambridge University, UK, estimated the monetary value of benefits from relatively intact biomes compared with those converted to intensive human use [12]. These include the tropical forest in Malaysia under reduced impact logging as opposed to conventional logging, and the tropical forest in Cameroon under reduced-impact logging or small-scale farming as opposed to conversion into oil-palm and rubber plantations.

In the case of Malaysia, the high-intensity, unsustainable logging was associated with greater private benefits through timber harvesting, but reduced social and global benefits through loss of non-timber forest products, flood protection, carbon stocks and endangered species. Summed together, the total economy value of the forest was some 14 percent greater when placed under more sustainable management.

In the case of Cameroon, conversion to oil palm and rubber plantations yielded negative private benefits, while social benefits from non-timber forest products, sedimentation control, and flood prevention were highest under sustainable forestry, as were global benefits from carbon storage and other values. Overall, the total economic value of sustainable forestry was 18 percent greater than that of small-scale farming, whereas it was negative for plantations.

The total economic value of sustainable uses of the forests were underestimated in that report, as only a handful of well-established ecosystem services were considered, while some particularly valuable services, such as nutrient cycling, waste treatment and the provision of cultural values were not examined.

It would appear that forestry is in for a complete shake-up, if we are to make the best use of a resource that's essential to the survival of our planet and its teeming biodiversity. All the more so as scientists have confirmed

that preserving existing forests and converting croplands to forests are by far the best options for saving on greenhouse gas emissions. Planting a forest would sequester two to nine times more carbon over a 30-year period than the emissions avoided by using same piece of land to grow bioenergy crops. Saving a forest also allows sustainable harvesting of wood wastes for burning directly or conversion into gas or liquid biofuels (see Chapter 5).

Overall, the total economic value of sustainable forestry was 18 percent greater than small-scale farming, whereas it was negative for plantations



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Sustainable Polycultures for Asia & Europe

Agro-forestry and other polycultures increase productivity and sustainability



Sheep browsing under trees in Scotland

Free grazing in coconut plantations

I first became involved with agro-forestry in a research project in Sri Lanka carried out in collaboration with the Coconut Research Institute in Lunawila. Large areas of Sri Lanka are covered with coconut plantations owned by large industries and by small farmers. Coconut trees do not form a dense canopy so it is always possible to grow other plants under the trees. Cattle are often seen grazing under the coconut trees, but the owners of the coconut trees are frequently not the owners of the cattle. The cattle belong to small poor farmers, and the owner of the coconut trees typically allows them to graze for free.

We set up an experiment to graze cattle under the coconut trees at a high stocking rate. In fact, the animals had much less food than they needed for maximum growth and reproduction (see Table 31.1) [1, 2].

The animals were old at calving, calving interval was long and milk yield was low. Supplementing the feed with imported rice straw improved the animals' reproductive performance and when they were also given rice bran, performance was further increased so that the calving interval was normal at 13 months

These results may be expected, but the unexpected was the beneficial effect on coconut

yield (see Table 31.2).

Grazing alone was sufficient to increase coconut yield by about 15 percent. No wonder the owners of the coconut trees were quite happy for the small farmers' animals to graze under them! This was due to a rapid turnover of biomass and the effect on soil quality seen here as water holding capacity. Bringing nutrients for the cattle from outside further increased coconut yield, as a result of the N, P and K etc contained in the feed (see Table 31.3).

The increased yield in coconut due to the animals is effectively an animal product; but that is often ignored. Since then, whenever I see animals grazing under trees or tied to trees I have often asked the question, what is the effect on production from the trees be it mango, coconut, durian or other fruit or on wood production e.g. teak. But there is seldom an answer.

Oil palm plantations

The effect of grazing animals on socio-economy became very apparent to me recently on a visit to an oil palm plantation in Bengkulu province of Sumatra, Indonesia. The Indonesian company that owns the plantations employed workers to collect palm fruit bundles from the plantation and carry them to a road passable by trucks. The employers had taken the initiative to give to the workers a Bali cattle (*Bos banteng*), for pulling a small cart that could hold about 15 to 20 bundles instead of the one carried by the worker. This increased the capacity of a worker to attend to 15 rather than 10ha. The feed for the cattle was plants growing under the trees plus leaves and core from the palm fronds, which had to be cut down before a palm bundle could be cut off. At night, the cattle were also given some palm sludge from the factory. It soon transpired that there was much more feed than one animal could eat so the farm workers were allowed to take several animals with them during the working day in the plantation. An average of six animals come with each worker in the morning. What is the possible stocking rate under palm oil trees? I was told maybe 2/ha even with full canopy. If so, many millions of cattle could be fed under oil palm trees in the world. These could provide a secure living for many families, though this is definitely not a recommendation for turning standing forests to oil palm plantation (see Chapters 5 and 30).

Similar effects on oil palm production were observed some years ago [3] (see table 31.4).

There were consistent increases in oil palm yield of some 15 to 20 percent as a result of grazing with cattle and goats in the plantation, probably a result of increasing turnover of biomass and soil water-holding capacity. The positive effects of livestock in agro-forestry are not unique to the tropics. The productivity of sheep grazing under trees in Scotland was similar [4.5], and in dry years greater than sheep grazing a similar area in open land. Evidently the growth of the trees was a bonus of animals grazing, and soil fertility improved.

Reforestation with the aid of small farmers and their complementary crops

In Indonesia where many forests have been illegally cut, the government is trying to re-establish the forests with the aid of small farmers living nearby. These farmers are given the right to cultivate and plant complementary crops between the trees, in this case teak and eucalyptus trees, until the full canopy has formed. One may question if the full canopy is necessary for optimal growth and quality of the trees. Less than full canopy could give small farmers continuous access to grazing and other complementary crops and maybe also to better quality trees.

	Age at calving month	Calving interval	Milk yield kg/d
Grazing	57	20	0.87
Grazing + rice straw	47	18	1.53
Grazing + rice straw + rice bran	40	30	2.36

Table 31.1. Effect of grazing and supplement of female cattle under coconut

	Nuts/palm	Copra/palm (kg)	Water holding capacity (mm/m)
Non Grazing	44.1	11.1	16.9
Grazing	47.9	13.3	18.3
Grazing + rice straw	50.6	14.2	18.9
Grazing + rice straw + rice bran	57.4	16.7	17.6

Table 31.2. Effect of grazing on annual coconut yield and soil water holding capacity [1]

	Content in coconut leaf (%)		
	N	P	K
Non Grazing	1.89	0.15	1.21
Grazing	1.86	0.15	1.18
Grazing + rice straw	1.92	0.16	1.48
Grazing + rice straw + rice bran	2.23	0.18	1.76

Table 31.3. Effect of grazing and supplement on coconut leaf composition after 6 years

Year	Grazed Area	Non-Grazed Areas	Difference
1981	30.55 (C)*	25.61	4.94
1982	17.69 (C)*	15.87	1.82
1983	25.12 (C & G)	22.97	2.15
1984	23.45 (C & G)	18.29	5.16

Fresh fruit bunches (metric t/ha)
*C = cattle: C & G = cattle and goats

Table 31.4. Effect of mixed cattle and goat grazing on annual yield of fresh fruits in oil-palm plantations in Malaysia

Inter-planting with leguminous trees and bushes for animal feed could capture N also for the forest trees. The way silvopastoral systems should be developed or perhaps more precisely redeveloped will vary environmentally according to climate, type of trees, type of animals and socio-economic circumstances. What's important here is not always the maximum production of trees, but the best total production of all the

components in the system, and the social benefits provided thereby. An added advantage is that such systems will be much more sustainable than monoculture tree systems and special animal systems.

Chickens and pigs after all were forest animals and not designed for large intensive stall-fed and battery-fed systems. The trees will also accumulate carbon from atmospheric CO₂ and therefore help in slowing down climate change. The relentless push to monoculture promoted recently by herbicide resistant GM crops cannot be the solution from environmental and socio-economic points of view.

Advantages of polyculture

In many tropical areas in developing countries, polyculture has been used for many years particularly in densely populated areas. This involves both combinations of forests with arable crops or grazing animals and a mixture of arable crops. Often three crops are grown together. Leguminous crops such as groundnut, soya bean and peas are frequently grown together with non-leguminous crops such as maize, cassava and wheat, so that the nitrogen captured by leguminous plants can be used also by non-leguminous plants. These crops are not harvested at the same time. Cassava for instance is generally harvested only once a year while other plants that have a much shorter season can be replanted. Combine harvesters cannot be used in this kind of harvesting; but as labour is typically not a problem, labour-saving devices provide no solutions and often create unemployment and poverty. polyculture systems such as these are sustainable and help to maintain soil fertility and high yields of crops.

Problems of monoculture

The negative effect of monoculture was demonstrated in rice production. Here herbicides had been recommended for use in the paddy fields; but instead of herbicides ducks were introduced (see Table 31.5) [6] (see also Chapter 26).

The ducks ate the weeds and the insects and increased the yield of the paddy. As the young

ducks were also fed at night they essentially brought some fertiliser to the paddy in the form of faeces. Now fish have also been introduced to consume the plankton grown in the paddy fields as a result of the ducks fertilising the paddy. The net income per ha increased by 20 to 30-fold

There are so many possibilities for increasing production in ways that are sustainable, that also contributes to mitigating climate change.



Cattle grazing in palm plantation, Sumatra

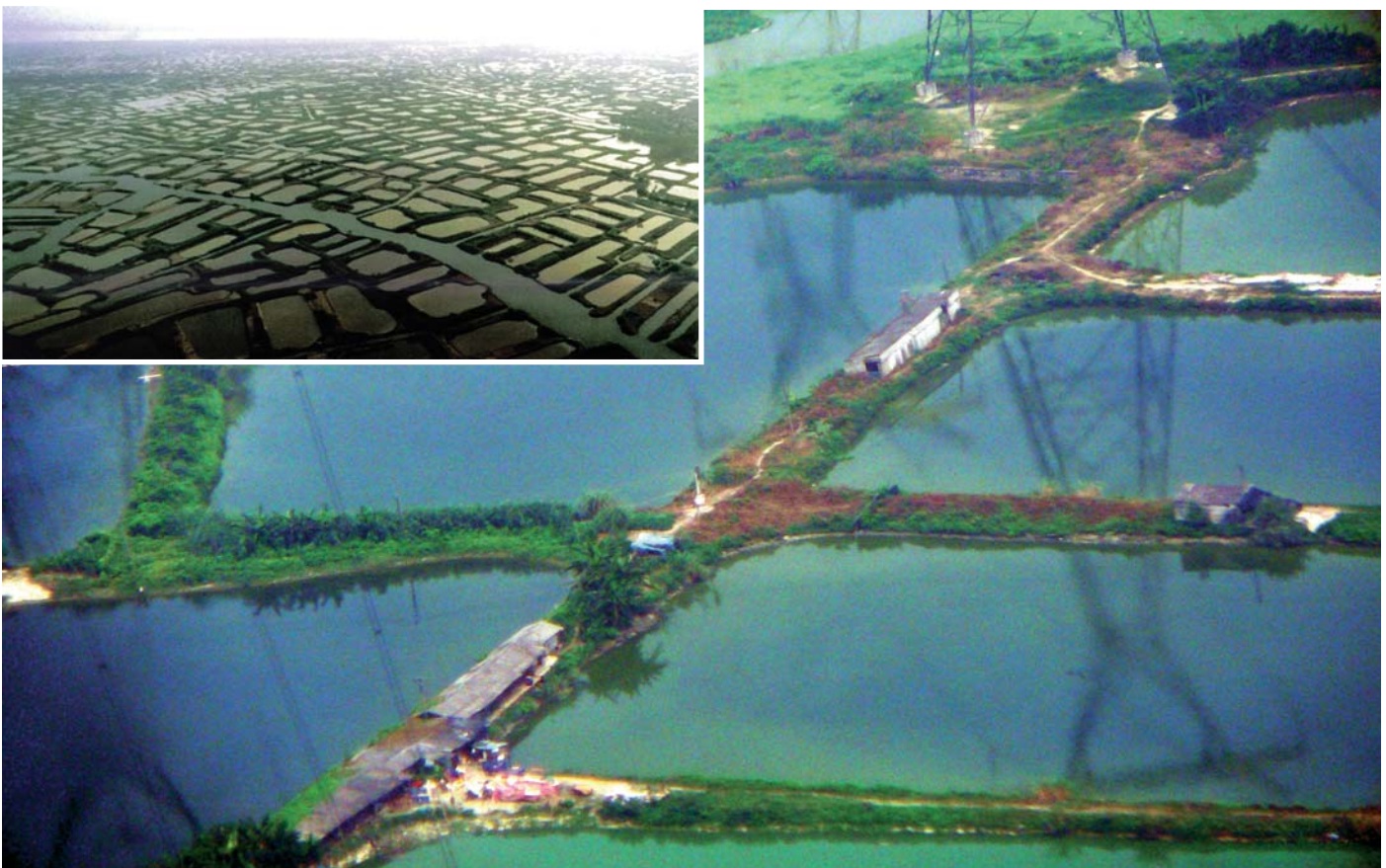
Systems Inputs:	Rice	Duck /Rice	Fish /Rice	Duck/ Fish /Rice	Layer-Duck/ Fish/ Rice
For rice	6.62	3.92	7.36	3.92	3.92
For duck	-	8.70	-	8.70	52.92
For fish	-	-	15.58	13.90	13.90
Total	6.62	12.62	22.94	26.52	70.74
Outputs:					
From rice	8.56	8.03	9.23	9.85	10.44
From duck	-	14.50	-	14.50	68.02
From fish	-	-	22.22	46.39	47.92
Total	8.56	22.53	31.45	70.74	126.38
Net benefit	+1.94	+9.91	+8.51	+44.22	+55.64

Table 31.5. Integrated system of rice, rice plus duck, rice plus fish, and rice plus fish and duck on net benefit for farmers (Mill. Vietnam Dong/ha)

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Circular Economy of the Dyke-Pond System

A land-water farming system developed over the past two thousand years offer strong support for the idea of that a sustainable system operate in closed cycles like an organisms



Getting the most from land and water

The clouds and mists cleared as we prepared to land in Guangzhou, and a remarkable landscape came into view. Like a mosaic of silver mirrors embedded in emerald, hundreds, if not thousands of ponds filled the spaces between the Pearl River tributaries as they meandered and fanned out into the South China Sea.

The ponds were predominantly narrow rectangles stacked broadside on, with shorter rectangles, squares, and irregular shapes pressed into service to fit the topography. The main effect was to leave cultivated strips of land and the occasional fields between adjacent bodies of water.

The Pearl River Delta of South China, sprawling over 12 000 km², is famous for its dyke-pond system of fish farming combined with

the cultivation of crops [1]. It contains one of China's richest and most densely populated agricultural areas, supporting an average of 17 persons per hectare.

The dyke-pond system evolved over the past two thousand years, perfected by generations of Chinese farmers into a 'circular' economy of intensive agriculture integrated with the polyculture of carps and other freshwater fishes, on a geographic and economic scale unrivalled elsewhere in the world. It depends on maximising internal inputs between land and water, optimising the efficient use of resources while minimising wastes.

The director of the Guangzhou Institute of Geography, Prof. Zhang Hongou, stressed that 'circular economy' is a guiding principle in mainstream Chinese thinking, as opposed to the

linear economy of the West. Perhaps that is at least partly why the Chinese economy has been growing mostly in double figures over the past decade.

Guangzhou Institute of Geography was established in 1958 as part of the Chinese Academy of Sciences, and in 1999, received recognition from the Chinese government as one of Ten National Distinguished Organisations. Among its accolades is the scientific study of the dyke-pond system pioneered by Prof. Zhong Gongfu and his colleagues in the 1970s, and its successful extension for flood control and improved land use (see later).

The Institute also researches on regional development in Guangdong, tropical and Chinese geography, environment and ecology, remote sensing and land use. It runs a web resource for remote sensing and environmental protection, and publishes a journal.

The Pearl River Delta of South China, sprawling over 12 000 km², is famous for its dyke-pond system of fish farming combined with the cultivation of crops. It contains one of China's richest and most densely populated agricultural areas, supporting an average of 17 persons per hectare

The dyke-pond system

In the late 1980s when Guangzhou Institute first carried out the survey, the main dyke-pond area covered 86 632 ha between the two major Pearl River tributaries, Xijiang and Beijiang, of which 30 321 ha (35 percent) were fishponds, combined with the cultivation of mulberry (10 395 ha, 12 percent) or sugar cane (15 593 ha, 18 percent). The remainder 30 322 ha (35 percent) was mainly irrigated rice (25 percent) and a variety of mixed or miscellaneous agriculture that includes dykes specialising in fruit trees, vegetables or decorative plants and flowers [1].

The pond is the heart of the system. To produce a pond, soil is excavated and used to build or repair the dykes surrounding it. Before it is filled with water, the pond is prepared by clearing, cleaning and fertilization with quick lime, tea-seed cake and organic manure from livestock kept on the dykes. Most ponds are rectangular, 0.4 to 0.6 ha in area and 2 to 3 m deep. The dykes are usually 6 to 10 m wide, and extend 0.5 to 1.0 m above the pond surface. Various fish species live at different pond depths, and have different feeding habits, thereby making full use of the water and the pond ecology. The typical poly-culture is a combination is the "four big family fish": grass carp (*Ctenopharygodon idellus*), silver carp (*Hypophthalmichthys molitrix*), big head carp (*Aristichthys nobilis*) and common carp (*Cyprinus carpio*), requiring little or no external input.

The pond mud, much enriched in nutrients, serves as fertiliser for crops. Ponds are drained two or three times a year, and the mud at the bottom is dredged up to put on the dykes, thereby raising and repairing the dykes and restoring the depth of the pond. Pond mud is also used for mushroom cultivation. Mushrooms are often cultivated on the floor of the silkworm shed in

winter, the off-season for silkworm production. After the final crop of mushrooms has been harvested, the mud-bed is used to fertilize vegetables, fruit trees and grasses.

The pond is filled with river water. Water also enters directly as rain and through runoffs from the dykes. Water leaves the pond via the pond drainage outlet in controlled discharges. It is also lost through evaporation and transpiration, via seepage into the dykes, and through being removed at regular intervals to 'fertigate' the crops growing on the dykes.

Livestock is an important link in the circular economy. Pigs, chickens and ducks are reared on the dykes, to provide manure to fertilise the fishponds, to encourage the growth of plankton that feed the fish.

Most dyke crops are fed directly to the fish, such as elephant grass for the grass carp, or else to the livestock, such as forage crops for pigs.

With a tropical to subtropical climate, the dyke-pond area is well endowed with sunshine and rainfall, and hence extremely productive, especially with a system that recycles and transforms all the "wastes" into nutrient resources.

The circular economy can be quite complex [1-3]. I have drawn a diagram of a simple system involving mulberry cultivation (see Fig. 32.1). Mulberry leaves are picked to rear silkworms, from which silk cocoons are harvested, while the wastes of silkworms are used to fertilise the pond to feed the fish. With only pigs and vegetables included, there are at least 11 cycles in the diagram varying in length from two to five links.

The external energy input is minimal, and consists of mainly labour and the energy expended to make farming implements, housing and equipment for rearing silkworms, and machinery and energy to aerate the fishpond and to dredge it. The major energy input by far, of more than 99 percent [2], is sunlight, and it is free.

There are numerous harvests, fishes, silk cocoons and vegetables being the major ones for the system depicted, pigs would be a minor harvest. Some harvests would include livestock such as chickens and ducks as well as mushrooms.

Fish sales contribute the largest source of income to the region's agricultural sector, some 50 percent of the total fish production of Guangdong Province and 80 percent of the nation's export in live fish.

Since the late 1970s, the traditional dyke-pond system of the Pearl River Delta has been undergoing dramatic changes. The first was a major shift from a collectivist to household production as part of the major rural reforms implemented throughout China. The second involves an intensification of production, a gradual supplementation of internal inputs with external inputs and a move away from the previously sustainable circular economy.

Dyke-pond system and flood control

About 1 000 years ago, the coastline of the Pearl River Delta was very different. The delta of Zhujiang, the most northern of the three major

tributaries, met the delta of Xijiang, the most southern tributary [4], and the lowlands were neither widely nor continuously cultivated on account of flooding and the presence of sulphuric acid soils. The villagers depended heavily on capturing and collecting marine, riverine and wetland resources. At higher elevations, however, fruits were cultivated, especially litchi (*Litchi chinensis*) and longan (*Euphoria longana*).

During the mid-fourteenth century, water control measures were started in the lower-lying areas. Small watercourses were dammed and dykes created to make fishponds. Ponds were dug to drain the marshes and natural ponds in order to create agricultural land, and the excavated soil was used to construct the dykes. The fishponds were stocked with carp fry naturally occurring in Xijiang.

The first commercial crops to be grown on the dykes were litchi and longan, but there were no conscious effort to integrate pond and dyke ecology until much later. By the 1620s, mulberry was widely cultivated on the dykes and the economic returns from the integrated mulberry dyke-fish pond systems were found to be greater than fruit-tree cultivation.

Thus, the circular economy of the dyke-pond system evolved out of a flood control measure, and it has been used effectively for the same purpose since. It will have worldwide applications as sea level rises in coastal areas, and in flood-prone areas fed by melting ice and glaciers (Chapter 1).

Outside the core region of the traditional dyke-pond system, there remains in Guangdong Province some 200 000 ha of flood-prone lowland, including the areas along the lower reaches of the main rivers and the coastal lowlands of the Zhujiang Delta. Most of these lowlands are seasonally flooded to depths of 1 to 1.5 m, and sometimes as much as 3 m of river and rainwater, exacerbated by a history of deforestation in the watersheds of Guangdong Province.

Since the 1950s, various measures have been taken to manage the flood-prone lands: building reservoirs and canals, contour ditching, sluice systems to raise the water in canals and to drain floodwaters; establishing a network of pumping stations to drain water from the flood plains into the canals; and reforestation in the highlands. In the coastal regions, earthen dykes were reinforced or replaced by concrete to improve resistance to typhoon-driven high tides, irrigation and drainage systems were separated by tunnels to lower the water-table, an electric pumping network was installed for drainage and irrigation and low-lying land was elevated by spreading soil.

These measures succeeded in reclaiming much of the flood-prone lowland, making agriculture possible and improving public health. Schistosomiasis (a disease spread by a parasitic worm) was eradicated. However, some 30 percent of the lowland by the rivers in Guangdong still remained to be brought into sustained productive use. This consists of widely scattered land in small pockets, or especially low-lying and not amenable to reclamation by other measures. Similarly, in the

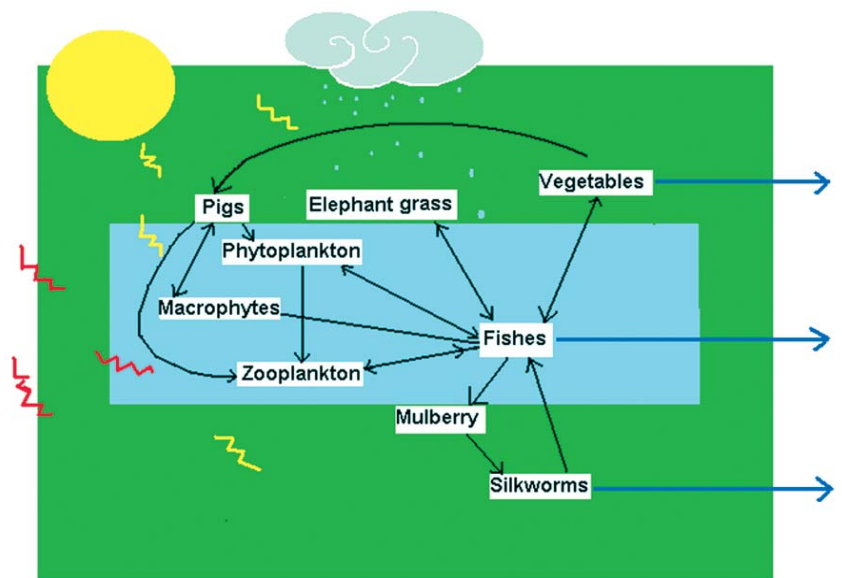


Figure 32.1. Circular economy of dyke-pond system

The circular economy can be quite complex which silk cocoons are harvested, while the wastes of silkworms are used to fertilise the pond to feed the fish. With only pigs and vegetables included, there are at least 11 cycles in the diagram varying in length from two to five links

coastal zone, despite the use of pumping stations for drainage and irrigation, crops yields remained low owing to high water tables and salination. The dyke-pond system has proven effective in transforming those waterlogged lowlands into productive sites. Fishponds were dug and the excavated sediment used to construct raised dykes and fields.

Scientists in the Guangzhou Institute of Geography started a research project in the early 1970s supported by the United Nations University [1-3, 5]. They established an experimental station in Shunde County in the heart of the dyke-pond region to study energy flow and material cycles in the newly established dyke-pond systems, and were able to document the successes [5].

The circular economy of the dyke-pond system evolved out of a flood control measure, and it has been used effectively for the same purpose since. It will have worldwide applications as sea level rises in coastal areas, and in flood-prone areas fed by melting ice and glaciers

Turning water-logged lowlands into productive dyke-pond systems

Deqing County, 240 km west of Guangzhou is one of the most seriously eroded regions in the Province. Many watercourses got silted up and the streambeds became higher than the surrounding fields, with the result that about 10 percent of the fields were waterlogged. Two tracts of lowlands were selected for introducing the dyke-pond systems in 1979.

The first, a 19 ha tract called Liangqintang normally yielded a single rice crop yearly, and was used for fish culture during the high-water season. Productivity was low, no more than 3.75 tonnes of rice/ha and 0.75 tonnes of fish/ha. Often, production failed altogether; and people referred to it as "a tract of three harvests in ten years".

The tract was converted to a dyke-pond system growing bananas and elephant grass (for fish feed). A small distillery and pigsties were constructed next to the pond. The distiller's grain was fed to the pigs and the pig wastes emptied into the pond. The 1981 fish harvest reached 3.0 tonnes/ha. In 1982, the total harvests (over all 19 ha) jumped dramatically to 125 tonnes of fish, 150 tonnes of bananas, and 75 tonnes of pork, not counting large amounts of vegetables. The net income for 1981 was already 7.6 times higher than in 1978 before the project began.

The second site selected in Deqing County was a tract of 2.7 ha of seasonally flooded lowland along the Xijiang River in Quianhoujie Village. It was converted into a mulberry dyke-pond with some vegetables. A pigsty was constructed near the pond. Mulberry leaves were fed to silkworms, the silkworm excrement and pig manure were emptied into the pond. The pond mud was used periodically to fertilize the dyke soil. By 1982, the net income increased 200 percent from 1981; and that in 1983 was 60 percent higher than 1982.

Doumen County, located in the southwestern part of the Zhujian Delta, has 40 percent of its land at 0.2 to 0.8 m below sea level. Electric pumps are commonly used to remove water from low-producing rice and sugarcane fields. A variety of dyke-ponds were successfully installed in the late 1970s, which then spread to the whole country.

The low-lying fields at Anfenwei in east Doumen are inundated annually for several months. Since 1979, 6 ha of fish ponds were dug to a depth of 2.5 to 3 m and the mud removed was spread over the fields at an average rate of 750 m³/ha/year. After several years, the fields were raised to sea level and no longer water-logged. The fields were planted in a

rice-sugarcane rotation and interplanted with vegetables. Pigs and poultry were raised close to the ponds and their excrement emptied into the ponds. Rice yields increased from 6 tonnes/ha/year to 7.5 tonnes/ha/year, and 4 tonnes of fish were harvested in addition to pigs and poultry. Electricity bills were reduced 20 to 30 percent annually because of decreased need for drainage pumping. Up to 1982, at least 700 ha of fish ponds have been dug in the entire county, and about 10 000 ha of low-lying fields have been elevated.

The Chenhai-Raoping district of 48.6 km² situated between Changhai and Raoping Counties in east Guangdong Province resulted from a reclamation and farming project completed in 1971. However, much of the area is still under water.

A research team from the Guangzhou Institute of Geography designed an integrated development programme including the dyke-pond system [6], and put the programme into operation in 1983. By 1987, remarkable improvements were achieved in all aspects, including the dyke-pond system. A total of 262 ha of ponds had been constructed yielding 5.805 tonnes fish/ha at a value of 6.08 million Yuan/year. Considerable amounts of vegetables and forage crops were also harvested from the dykes.

Dyke-pond system under pressure from industrial growth

These remarkable successes were not followed up, however. Practically all the academics involved in the dyke-pond projects had soon retired or were near retirement, and market forces and other pressures of rapid industrialisation came into play.

"China has developed too quickly, at 10 to 20



percent growth in GDP a year," the Institute director Prof. Zhang said, "This has placed agriculture under great pressure. Industrialisation has led to a decrease in land available for agriculture, and the pressure to produce more from less land has resulted in increased pollution."

The professors of the dyke-pond system, Zhong Gonfu, Wu Houshui, Deng Hanzeng and Liang Kuo Ziao, now all retired, came to meet with us to explain their work, thanks to the tireless efforts of Prof. Zhong Ying, daughter of Zhong Gongfu, who acted as our guide and mentor throughout the most enjoyable and productive five days we had in Guangzhou. She and Prof. Wu Houshui accompanied us for a day tour to important sites, including the dyke-pond region, or what is left of it today.

The experimental station where they carried out precise measurements on energy and material flows has long since gone, and many of the sites they surveyed or worked on have disappeared. Prof. Wu Houshui estimates that perhaps half of the pond-dyke area may have gone under the pressure of industrial development. All agreed that there was a need for projects like Dream Farm 2 [7], a practical implementation of the idea of creating sustainable systems modelled after the organism, which maximises closed cycles [8-10].

Industry, ingenuity and market forces

The success of the dyke-pond system owes a lot to the particular combination of ingenuity and industry of Chinese farmers, and it is still much in evidence today.

The farmers are extremely skilled at maximising the use of space, time and resources; but a commitment to hard work is also necessary. Gourds and melons are trained on trellises overhanging ponds and drainage ditches, and crops are planted together so that sun-loving species provide shade for those requiring it. Plantings are timed so that several harvests are obtained from the same piece of land.

Where sugarcane is planted, the main product is sugar, but the young leaves are fed to fish and pigs, and old leaves used to shade vegetable gardens. Refinery wastes are returned to the dyke pond as fish and animal feed. Bamboos are often planted to provide poles for construction and materials for making baskets, traps, screens,

trellises and frames. Bamboo wastes are also used as fuel.

During our all too brief tour of the dyke-pond region, we met a farmer by the roadside, knee deep in the drainage ditch, dredging up the black mud from the bottom of the ditch to put onto her vegetable garden that reached right up to the water margin of the ditch. Her garden is a perfect example of the intensive and ingenious use of limited land. The Chinese government gave her one fen of land (one-tenth of a Chinese mu = 0.0667 ha), but she grows enough to feed her own family, with plenty left over to sell on the market. She offered to invite us to lunch on the spot, on hearing that we were from London in the UK; unfortunately we were unable to accept her due to the lack of time.

Other ingenious use of the pond was to raise ducks, the faeces of which go directly to fertilise the fish and we saw plenty of that.

Fish farming can be very profitable, but is also increasingly at the mercy of market prices. Chinese love good food to extreme, and restaurant meals are a must for any visitors (fortunately for us). The foyer of restaurants in Guangzhou is typically filled with aquariums exhibiting live fish that you can choose for your meal with the price per catty clearly marked, and it is considered impolite to choose cheap fish for the guests. Any fish that became too available would become cheap, no matter how tasty it is, and hence could bankrupt the fish farmer overnight.

We saw signs of intensification of fish farming that was clearly unsustainable. A worker was hired to feed cut-up frozen sea fish to some highly priced carnivorous fish reared in a pond owned by someone else, and the feeding shed was filled with "fish medicines" to control diseases and parasites probably brought in by the feed, and by the pond being too heavily stocked. The price of the feed was 1.50 Yuan per catty, while the fish in the pond was fetching \$15 per catty in the market.

High stocking rates of fishponds, external feeds, diseases, and "fish medicines" all contribute to fouling the pond water, which becomes a serious source of pollution when drained into the rivers and lakes. Intensive fish farming has indeed become an ecological problem in search of a solution, and Dream Farm 2 could well offer a way forward (see Chapter 34).



- 33 -

Dream Farm

Abundantly productive farms with zero input and zero emission powered by waste-gobbling bugs and human ingenuity



Environmental engineer meets Chinese peasant farmers

Doesn't it sound like a dream to be able to produce a super-abundance of food with no fertilizers or pesticides and with little or no greenhouse gas emission? Not if you treat your farm wastes properly to mine the rich nutrients that can support the production of fish, crops livestock and more, get biogas energy as by-product, and perhaps most importantly, conserve and release pure potable water back to the aquifers.

That is what Professor George Chan has spent years perfecting; and he refers to it as the Integrated Food and Waste Management System (IFWMS) [1].

Chan was born in Mauritius and educated at Imperial College, London University in the United Kingdom, specializing in environmental engineering. He was appointed director of two important US federal programmes of the US Environmental Protection Agency and the US Department of Energy in the US Commonwealth of the Northern Mariana Islands of the North Pacific.

On his retirement, Chan spent 5 years in China among the Chinese peasants, and confessed he learned just as much there as he did in University, especially from the circular economy of the dyke pond system in the Pearl River Delta (see previous Chapter).

What he learned was a system of farming and living that inspired him and many others including Gunter Pauli, the founder and director of the Zero Emissions Research Initiative (ZERI) (www.zeri.org).

Chan left China in 1989, and continued to work with Gunter and others in ZERI through consultancy services. This work has taken him to nearly 80 countries and territories, and contributed to evolving IFWMS into a compelling alternative to conventional farming.

The integrated farm typically consists of crops, livestock and fishponds. But the nutrients from farm wastes often spill over into supporting extra production of algae, chickens, earthworms, silkworms, mushrooms, and other valuables that bring additional income and benefits for the

Box 33.1

How volatile nitrogen is turned into nutrient for plants [4]

Livestock manure contains large amounts of ammonia gas that must be turned back into stable nitrate before it can be absorbed as nutrient by plants. Nitrification is the process in which soil bacteria oxidize ammonia (NH_3) sequentially into nitrite (NO_2) and then nitrate (NO_3). Ammonia is oxidized into nitrite by bacteria belonging mainly to the genus *Nitrosomonas*, but also *Nitrosococcus*, *Nitrosospira*, *Nitrosolobus* and *Nitrosovibrio*. Nitrite is then further oxidized into nitrate by bacteria belonging mainly to the genus *Nitrobacter*, but also by bacteria in other genera such as *Nitrospina*,

farmers and the local communities.

Treating wastes with respect

The secret is in treating wastes to minimize the loss of valuable nutrients that are used as feed to generate further nutrients from algae, fish, etc., that feed a variety of crops and livestock. At the same time, greenhouse gases emitted during the first phase of waste treatment are harvested for use as fuel, while the oxygen required in the second phase of waste treatment - which gets rid of toxins and pollutants - is generated by photosynthetic algae, so fish stocks are not suffocated through lack of dissolved oxygen in the nutrient-rich water entering the ponds.

Livestock wastes are first digested anaerobically (in the absence of air) to produce biogas (mainly methane). The partially digested wastes are then treated aerobically (in the presence of air) in shallow basins that support the growth of green algae. By means of photosynthesis, the algae produce all the oxygen needed to oxidise the wastes to make them safe for fish. This increases the fertilizer and feed value in the fishponds without robbing the fish of dissolved oxygen. All the extra nutrients, therefore, go to improve productivity. Biogas is used as a clean energy source for cooking, and also enables farmers to process their produce for preservation and added value, reducing spoilage and increasing the overall benefits.

IFWMS has the potential to revolutionize conventional farming of livestock, aquaculture, horticulture, agro-industry and allied activities, especially in non-arid tropical and subtropical regions. It can solve most of the existing economic and ecological problems and provide the means of production such as fuel, fertilizer and feed, increasing productivity many-fold.

"It can turn all those existing disastrous farming systems, especially in the poorest countries into economically viable and ecologically balanced systems that not only alleviate but eradicate poverty." Chan says [2].

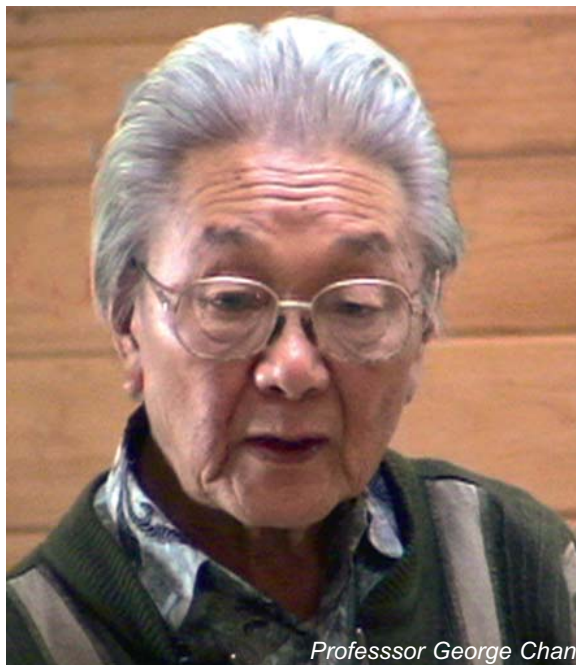
Increasing the recycling of nutrients for greater productivity

The ancient practice of combining livestock and crop has helped farmers almost all over the world. Livestock manure is used as fertilizer, and crop residues are fed back to the livestock.

Chan points out, however, that most of the manure, when exposed to the atmosphere, loses up to half its nitrogen as ammonia and nitrogen oxides, before they could be turned into stable nitrate that plants use as fertilizer (see Box 33.1). The more recent integration of fish with livestock and crop has helped to reduce this loss [3].

The important addition of a second production cycle of nutrients from fish waste has enhanced the integration process, and improved the livelihoods of many small farmers considerably. But too much untreated waste dumped directly into the fishpond can rob the fish of oxygen, and end up killing them.

In IFWMS, the anaerobically digested wastes



Professor George Chan

In IFWMS, the anaerobically digested wastes from livestock are treated aerobically before the nutrients are delivered into the fishponds to fertilize the natural plankton that feed the fish without depleting oxygen. In this way fish yield is increased three- to four-fold, especially with the polyculture of many kinds of compatible fish feeding at different levels

from livestock are treated aerobically before the nutrients are delivered into the fishponds to fertilize the natural plankton that feed the fish without depleting oxygen. In this way fish yield is increased three- to four-fold, especially with the polyculture of many kinds of compatible fish feeding at different levels as practiced in China, Thailand, Vietnam, India and Bangladesh [5]. The fish produce their own wastes that are converted naturally into nutrients for crops growing both on the water surface and on dykes surrounding the ponds.

The most significant innovation of IFWMS is thus the two-stage method of treating wastes.

Chan is critical of the "erratic proposals" of experts, both local and foreign, to spread livestock wastes on land to let them rot away and hope that there are a small amount of residual nutrients left, after tremendous losses that damage the environment have taken place.

According to the US Environment Protection Agency, up to 70 percent of nitrous oxide, N_2O , a powerful greenhouse gas with a global warming potential of 280 (i.e., 280 times that of carbon dioxide) comes from conventional agriculture [5]. Nitrous oxide is formed as an intermediate in denitrification, a process in which soil bacteria reduce nitrate ultimately back to nitrogen gas. Denitrifying bacteria belong to two main genera, *Pseudomonas* and *Bacillus* [6]. Animal manure could be responsible for nearly half of the N_2O emission in agriculture in Europe, according to some estimates; the remainder coming from inorganic nitrate fertilizer [7]. Thus, anaerobic

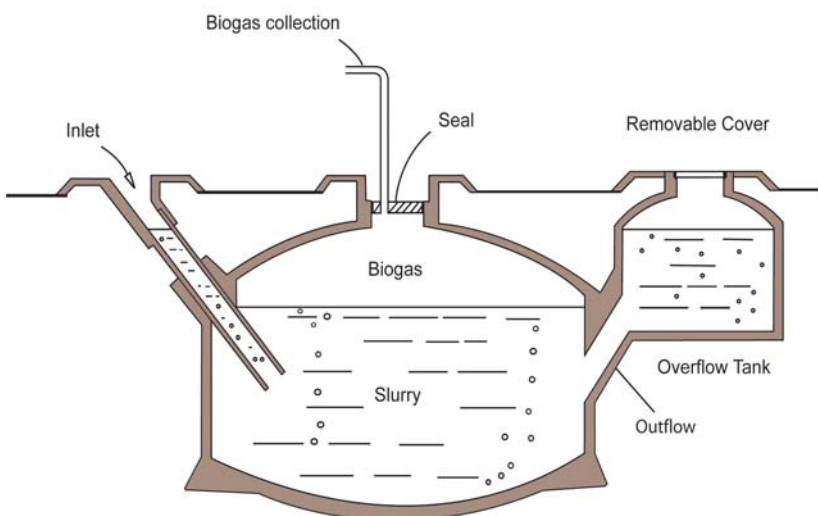


Figure 33.1. The China Dome digester

digestion not only prevents the loss of nutrients, it could also substantially reduce greenhouse gas emissions from agriculture.

Chan further dismisses the practice of composting nutrient-rich livestock wastes [8], for this ends up with a low-quality fertilizer that has lost ammonia and nitrite. Instead of mixing livestock wastes with household garbage in the compost, Chan recommends producing high-protein feeds such as earthworms from the garbage, and using worm casts and garbage residues as better soil conditioners. He is also critical of the outmoded practice of putting manure in septic tanks for very little financial or other benefit while the badly treated effluent is just as dangerous as the waste itself.

Instead, the livestock waste digested anaerobically followed by oxidation in open shallow basins with natural algae before letting the treated waste effluent flow into the fish pond, can convert almost 100 percent of the organic nutrients into inorganic nutrients that will not consume any oxygen to deprive the fish. So, theoretically, the quantity of waste input into the pond can increase 10-fold without the risk of pollution. But, Chan cautions, the nutrients in the waste must be totally

used by both fish and crop culture, or the nutrients can create problems of eutrophication - over-enrichment of plankton - that uses up all the oxygen in the pond, thereby lowering productivity.

To close the circle, livestock should be fed with crops and processing residues, not wastes from restaurants and abattoirs. Earthworms, silkworms, fungi, insects and other organisms are also encouraged, as some of them produce high value goods such as silk and mushrooms.

The digester can be as simple as a couple of concentric plastic bags of 5m³ capacity or 200-litre drums for a small farm, or a complex reinforced concrete steel structure with an anaerobic sludge blanket to collect the biogas for a big farm or industrial enterprise.

One typical construction is the China Dome digester (see Fig. 33.1). As the fresh wastes enter the digester, the waste-eating bacteria transform the unstable ammonia (NH₃) and nitrite (NO₂) into stable nitrate (NO₃), which is ready for use as fertilizer. As more wastes are added, the digester also produces an abundant and inexhaustible supply of biogas - 2/3 methane (CH₄) and 1/3 carbon dioxide (CO₂) - a convenient source of free and renewable energy for domestic, farming and industrial uses (see Box 33.2). Big farms, meat and fish-packing plants, distilleries, and various agro-industries are now self-sufficient in energy, besides having big volumes of nutrient-rich effluent for fertilizing fishponds, and 'fertigation' (fertilization and irrigation) of many kinds of crops.

Proliferating lifecycles for greater productivity

The aerobic treatment in the shallow basins depends on oxygen produced by the green alga *Chlorella*. *Chlorella* is very prolific and can be harvested as a high-protein feed for chickens, ducks and geese.

When the effluent from the *Chlorella* basins reaches the fishpond, little or no organic matter from the livestock waste will remain, and any residual organic matter will be instantly oxidized by some of the dissolved oxygen. The nutrients are now readily available for enhancing the prolific growth of different kinds of natural plankton that

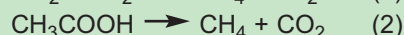
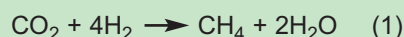
Box 33.2

Formation of biogas [9]

Certain bacteria naturally present in manure produce a combustible gas (biogas) when they digest organic matter anaerobically (in the absence of oxygen). Biogas typically contains between 60 and 70 percent methane. Anaerobic digestion involves two groups of bacteria.

The first group of ordinary bacteria produces organic acids such as acetic acid by fermentation. The second group of bacteria, the methanogens (methane makers), is special; these bacteria break down the organic acids and produce methane as a by-product.

Methanogens cannot tolerate oxygen and are killed when exposed to oxygen. Instead, they can use the dead end products of fermentation, carbon dioxide or organic acids such as acetic acid, to generate methane:



Methanogens are found wherever oxygen is depleted, such as wetland soils, aquatic sediments and in the digestive tracts of animals. Methane formation is the final step in the anaerobic decay of organic matter when carbon dioxide and hydrogen accumulate, and all oxygen and other electron acceptors are used up.

feed the polyculture of 5 to 6 species of compatible fish. No artificial feed is necessary, except locally grown grass for any herbivorous fish.

The fish waste, naturally treated in the big pond, gives nutrients that are used by crops growing in the pond water and on the dykes [10].

Fermented rice or other grain, used for producing alcoholic beverages, or silkworms and their wastes, can also be added to the ponds as further nutrients, resulting in higher fish and crop productivity, provided the water quality is not affected.

Trials are taking place with special diffusion pipes carrying compressed air from biogas-operated pumps to aerate the bottom part of the pond, to increase plankton and fish yields.

Apart from growing vine-type crops on the edges of the pond and letting them climb on trellises over the dykes and over the water, some countries grow aquatic vegetables floating on the water surface of lakes and rivers. Others grow grains, fruits and flowers on bamboo or long-lasting polyurethane floats over nearly half the surface of the fishpond water without interfering with the poly-culture in the pond itself. Such aquaponic cultures have increased the crop yields by using half of the millions of hectares of fishponds and lakes in China. All this is possible because of the excess nutrients from the integrated farming systems.

Planting patterns have also improved. For example, rice is now transplanted into modules of 12 identical floats, one every week, and just left to grow in the pond without the need to irrigate or fertilize separately, or to do any weeding, while it takes 12 weeks to mature. On the 13th week, the rice is harvested and the seedlings transplanted again to start a new cycle. It is possible to have 4 rice crops yearly in the warmer parts of the country, with almost total elimination of the back breaking work previously required.

Another example is aquaponic cultures of fruits and vegetables in a series of pipes. The final effluent from the aquaponic cultures is polished in

earthen drains where plants such as Lemna, Azolla, Pistia and water hyacinth remove all traces of nutrients such as nitrate, phosphate and potassium before the purified water is released back into the aquifer.

Processing for added value and nutrient release

One big problem with agricultural produce is the drop in prices when farmers harvest the same crops at the same time. This is solved by the abundant supply of biogas energy, which enables simple processing to be done, such as smoking, drying, salting, sugaring, and pickling.

Finally, the sludge from the anaerobic digester, the algae, macrophytes, crop and processing residues are put into plastic bags, sterilized in steam produced by biogas energy, and then injected with spores for high-priced mushroom culture.

The mushroom enzymes break down the ligno-cellulose to release further nutrients and enrich the residues, making them more digestible and more palatable for livestock. The remaining fibrous residues can still be used for culturing earthworms, which provide special protein feed for chickens. The final residues, including the worm casts, are composted and used for soil conditioning and aeration.

Model for sustainable development

Chan's dream farm shows how to grow and develop in a balanced way by closing the overall production cycle, then using the surplus nutrients and energy to support as many different cycles of activity as possible rather like a developing organism. I shall elaborate on this in the final chapter.



Box 34.1

Benefits of Dream Farm 2

1. Assembles in one showcase all the relevant technologies that can deliver sustainable food and energy and a profitable zero carbon economy
2. Generates all its own energy for heating and electricity, including clean fuel for transport
3. Energy use at the point of production enables combined heat and power generation improves efficiency by about 60 percent
4. Runs entirely without fossil fuels
5. Saves substantially on carbon dioxide emissions, by preventing methane and nitrous oxide escaping, by substituting for fossil fuels and by improved energy efficiency
6. Increases sequestration of carbon in soil and in standing biomass, thereby significantly mitigating global warming.
7. Reduces wastes and environmental pollution to a minimum
8. Conserves and purifies water and controls flooding (see Chapter 32)
9. Produces a diversity of crops, livestock and fish in abundance
10. Fresh and nutritious food free from agrochemicals produced and consumed locally for maximum health benefits
11. Provides employment opportunities for the local community
12. Provides a showcase and incubator for how appropriate new energy and food technologies are implemented
13. Provides hands-on education and research opportunities at all levels from infants to university students and beyond
14. Supports and promotes similar farms in the UK and all over the world

generates biogas, which provides all the energy needs for heating, cooking and electricity. The partially cleansed wastewater goes into the algal basin where the algae produce by photosynthesis all the oxygen needed to detoxify the water, making it safe for the fish. The algae are harvested to feed chickens, ducks, geese and other livestock. The fishpond supports a compatible mixture of 5-6 fish species. Water from the fishpond is used to 'fertigate' crops growing in the fields or on the raised dykes. Aquaculture of rice, fruits and vegetables can be done in floats on the surface of the fishpond. Water from the fishpond can also be pumped into greenhouses to support aquaculture of fruits and vegetables. The anaerobic digester yields a residue rich in nutrients that is an excellent fertiliser for crops. It could also be mixed with algae and crop residues for culturing mushrooms after steam sterilisation. The residue from mushroom culture can be fed to livestock or composted. Crop residues are fed back to livestock. Crop and food residues are used to grow earthworms to feed fish and fowl. Compost and worm castings go to condition the soil. Livestock manure goes back into the anaerobic digester, thus closing the grand cycle. The result is a highly productive farm that's more than self-sufficient in food and energy.

These farms are strong on animal welfare [5]. The animals are organically fed, and pigs are especially easy to toilet-train to deposit their manure directly into the digester, so their living quarter are spotlessly clean, which makes for healthy and contented animals.

Dream Farm 2

'Dream Farm 2' incorporates renewable energies explicitly into Chan's Dream Farm 1, with emphasis on nested coupled cycles in its operation. It consciously integrates food and energy production, with consumption at the point of production.

The ideal Dream Farm 2 operates as a farm, but also serves as a demonstration, education and research centre, and incubator for new ideas, designs and technologies. The aim is to promote and support similar farms all over the world, by collating and analysing data from similar farms, providing resources and facilitating information exchange [6] (see Box 34.1).

Most significant of all, it runs entirely without fossil fuels, and could even substitute for all fossil energy uses away from the farm, as we shall see.

The ideal Dream Farm 2 is presented in Figure 34.2. The diagram is colour coded to emphasize the major components: Pink is energy, green is food, blue is water purification, conservation and flood control, black is waste in the common sense of the word, though in Dream Farm 2, it rapidly becomes transformed into resources for producing energy or food. Purple is the analytical laboratory on site, which links to many other labs. It will be able to do water, gas and soil analyses on site, to monitor how the system is working. Modelling and forecasting could be done on site as well.

Because this is an organic system in the sense described, we don't have to have all the elements, or all at once. We can have a very simple system consisting of biogas digesters, livestock, crops, algae basins without fishponds, as that essentially does the water purification already and closes the cycle. The algae can be used to feed livestock, as an alternative to grain or soybeans.

The more experimental and innovative technologies, for example, hydrogen production directly from wastes [7, 8], fuel cells [9] for combined heat and power generation, using green algae for carbon capture and storage [10] etc., can all be added on and perfected while the farm is running and producing, which is very important

Another possibility with woody wastes that do not break down easily in the biogas digester is to turn them into charcoal by pyrolysis (smouldering) to generate heat, and then burying them to encourage crops to grow. Scientists now agree

Box 34.2**Advantages of anaerobic digestion to recover methane [6]**

- Potential to provide 3.2 percent of all energy needs or 12.9 percent of transport fuels in the UK (see Box 34.3) (NB previous estimates based on unreliable data now corrected, the basis of the estimates given in Box 34.3)
- Methane can be used as fuel for mobile vehicles or for combined heat and power generation (see main text)
- Methane-driven cars are already on the market, and currently the cleanest vehicles on the road by far
- Biogas methane is a renewable and carbon mitigating fuel (more than carbon neutral)
- Saves on carbon emission twice over, by preventing the escape of methane and nitrous oxide into the atmosphere and by substituting for fossil fuel; potential savings of 7.5 percent of national greenhouse gas emissions in the UK
- Conserves plant nutrients such as nitrogen and phosphorous for soil productivity
- Produces a superb fertilizer for crops as by-product
- Prevents pollution of ground water, soil, and air
- Improves food and farm hygiene, removes 90 percent or more of harmful chemicals and bacteria
- Can be adapted to produce hydrogen either directly or from methane

that the exceptionally fertile 'black earth' found in sites of prehistoric settlements in the Amazon is where indigenous tribes have buried the ashes and charcoal intentionally to help crops grow. The particles of char produced in this way are able to retain nutrients and water that might otherwise be washed down and away from the roots, and harbour micro-organisms that turn the soil into a spongy, fragrant, dark material [11]. Eprida, a "for-profit social-purpose enterprise" in Athens Georgia in the United States is marketing an improved process to farmers. Its selling point is to increase crop productivity to quite remarkable extents, and sequester a lot of carbon in the soil at the same time. This prehistoric process is still not completely understood scientifically, and there are research and business opportunities. The process is now commercially exploited to produce bio-oil (for fuel use) as well as bio-charl [12].

Anaerobic digestion offers numerous advantages over other biofuels

Anaerobic digestion is the core waste-treatment and energy technology in Dream Farm 2 as in Dream Farm 1. It has numerous advantages over other such technologies, including biofuels from crops (see Box 34.2). We presented our case in the UK Parliament in 2006 [6] at the launch of ISIS' Energy Report [13].

Anaerobic digestion is a boon for Third World countries, as it provides a labour-saving smokeless fuel for cooking (much healthier for women and children), a means of generating electricity for lighting that extends social and working hours, and improved sanitation [14]. The Chinese government is promoting the widespread use of biogas digesters to support a burgeoning eco-economy (see Chapter 32); they provide some of the necessary energy while preventing more than 90 percent of the environmental contamination [15].

In addition to combined heat and power generation that improves the efficiency of energy use by at least 50 percent, biogas methane is by far the cleanest fuel for mobile use [16]. Biogas methane-powered cars were voted environmental cars of the year in 2005.

Sweden has taken to anaerobic digestion for producing energy on a large scale, with small local farm-scale digesters comprising 10 percent. There is a well-organized network between producers and consumers. The Swedish Government is promoting a vision of biogas as the vehicle fuel of the future [17]. Its agricultural sector is given a significant role, and told to generate 11 000 GWh/year by 2050, more than a 10-fold increase from the current 800 GWh/y. Biogas is most suitable for transport within city areas, and local fleets are already operating in Gothenbur, Linköping, and Stockholm.

Since our presentation in the UK Parliament, the Government has published an Anaerobic Digestion Working Paper [18] committing the nation to making the most of anaerobic digestion for mitigating climate change. Its Department of the Environment, Food and Rural Affairs (Defra) has created the cross-Defra Anaerobic Digestion Project to deliver this commitment [19].

The potentials of methane fuel from anaerobic digestion to save on energy and greenhouse gas emissions for the UK are presented in Box 34.3. The estimate is conservative; using low ends of yields for mixed substrates.

Although the potential for anaerobic digestion is now widely acknowledged, there are major obstacles for its adoption. While millions of small-scale anaerobic digesters are working successfully internationally, high failure rates of



Dream Farm 2

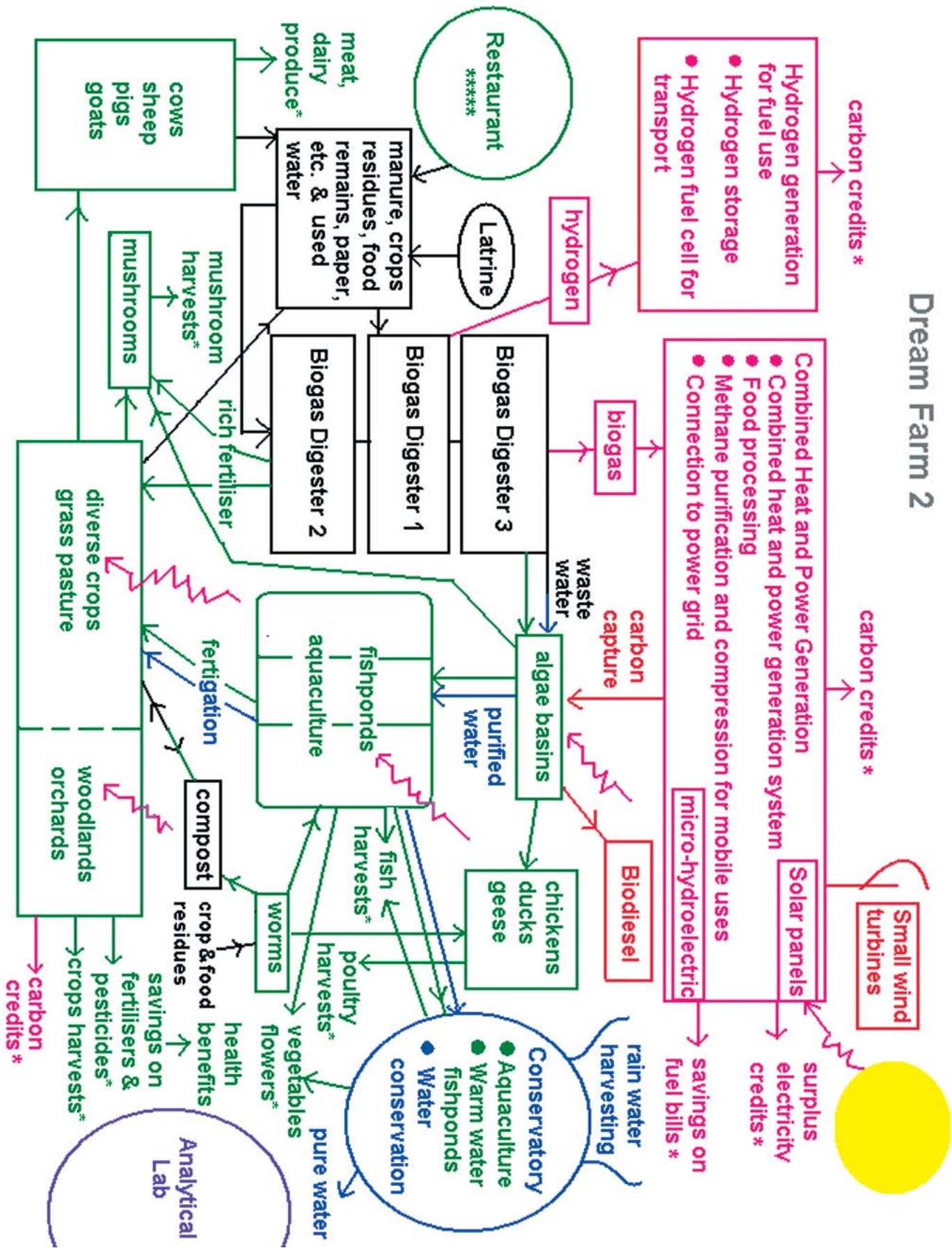


Figure 34.2. Dream Farm 2

Box 34.3

Methane Fuel from Anaerobic Digestion of Biological Wastes Potential Savings in Energy and Greenhouse Gas Emissions for UK

3.2% of total energy consumption
12.9% of transport
7.5% of greenhouse gas emissions

Energy

Total solid waste suitable for anaerobic digestion in UK	54 Mt [14] @ 100 m ³ biogas/t [15]/60 m ³ methane	129.60 PJ
Livestock manure [16, 17]:		
Cattle	138.50 Mt @ 25 m ³ /t [15]	
Sheep & goats	35.50 Mt @ 25 m ³ /t [15]	
Pigs	5.35 Mt @ 30 m ³ /t [15]	
Poultry	3.22 Mt @ 80 m ³ /t [15]	
Total		114.43 PJ
Crop residue (assume same as harvests [18])	41.2 Mt @ 100 m ³ biogas/t	98.86 PJ
Total methane energy from anaerobic digestion		342.89 PJ
UK total energy use in 2005 [19]		10 590.01 PJ
UK total energy consumed in transport 2005 [19]		2650.28 PJ

Greenhouse gas emissions

Savings from preventing release (assume 10 percent of methane yield)	857.21 Mm ³ ~ 617 191.2 t CH ₄ = 14.195 Mt CO ₂ e
At global warming potential of 23 [20]	
Savings from substituting for fossil energy	23.688 Mt CO ₂ e
Total savings from methane	37.883 Mt CO ₂ e
Savings from nitrous oxide prevented (GWP289) [20]	~ 40 000 t = 11.560 Mt CO ₂ e
Total savings from methane and nitrous oxide	49.443 Mt CO₂e
UK total greenhouse gas emissions 2005 [21]	657.000 Mt CO ₂ e

about 50 percent are experienced in the US [28]. There are also significant barriers to adopting the technology: high capital cost, improper design, poor construction, inadequate maintenance, and lack of economic return. Our own investigation suggests that there has been a tendency to 'over-design', with incorporation of high-tech monitoring and controls to optimise biogas production; all of which result in a lack of robustness. In general, a good biogas digester should yield its volume of biogas a day, with a liquid feed containing 8 to 10 percent solids.

Potential of Dream Farm 2 for mitigating climate change and freeing the world from fossil fuels

If Dream Farm 2 were universally adopted over the world, it would have the potential to save at least 19.7 percent of energy consumption and 37.0 percent of greenhouse gas emissions (see Box 34.4), not counting the extra renewable zero carbon energies incorporated: solar, wind and microhydroelectric, nor the carbon sequestered in standing crop biomass (see backcover diagram). For details on energy and carbon savings other than anaerobic digestion, please refer back to Chapter 19, Box 19.2.

A combination of solar, wind and

microhydroelectric as well as biogas could well provide over and above energy needs on the farm, and the excess energy could be fed into the grid system for supplying local homes and businesses. Consuming energy locally at or near the point of production increases energy use efficiency by some 60 percent, because any 'waste' heat generated (typically about 50 percent of the energy) could be used, and losses due to long distance transfer are minimised. This increase in efficiency could reduce fossil energy use by another 30 percent, and hence save another 17 percent of ghg emission. **Thus, it would not be surprising if fossil energies could be eliminated altogether.**

As Robert Ulanowicz says, "I'll bet people will be surprised at how quickly the carbon dioxide levels in the atmosphere can come down if we stop burning fossil fuels." I think he may well be right.

Dream Farm and the new paradigm

The final Section of this volume has provided abundant examples of key contributions to sustainable agriculture coming from local farmers and scientists working outside the dominant knowledge system and often in conflict with it. That is why some development specialists have been calling for a transformation of the dominant

knowledge system (see Chapters 1 and 2)

My own work on the physics of organisms [1, 29] has led me to the view that contemporary Western science is already undergoing a paradigm shift away from the mechanical framework of reductionist science, and towards an organic, holistic perspective that has deep affinities with indigenous knowledge systems across the world [30]. The new genetics of the fluid genome (see Chapter 2) is part of that paradigm shift. Dream Farm too, is part of the new paradigm, and this can be seen most clearly in how the model of sustainable system as organism contrasts with the dominant model

Model of sustainable system as organism vs the dominant model

The key to how organisms survive and thrive is the same as what makes a system sustainable. It involves maximising cycles and reciprocal, cooperative interactions, using the output of each cycle to feed another, and closing the grand cycle in a balanced way. This is diametrically opposed to the dominant neo-liberal model of infinite growth based on unbridled competition.

Let me explain these ideas with a few evocative diagrams. The dominant model of infinite competitive growth is represented in Figure 34.3.

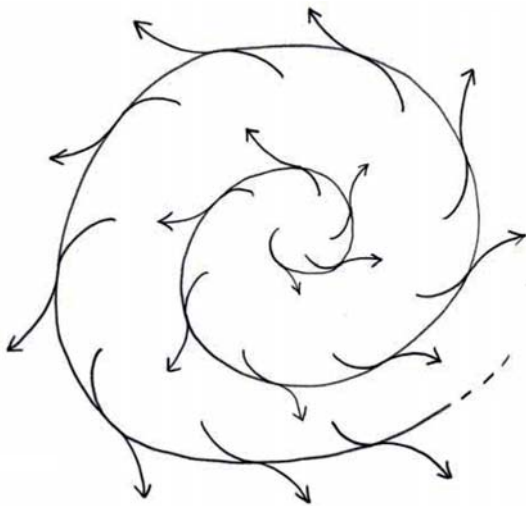


Figure 34.3. The dominant economic model of infinite unsustainable growth that swallows up the earth's resources and exports massive amounts of wastes and entropy

The system grows relentlessly, swallowing up the earth's resources without end, laying waste to everything in its path, like a hurricane. There is no closed cycle to hold resources within, to build up stable organised social or ecological structures.

In contrast, the archetype of a sustainable system is a closed lifecycle (Fig. 34.4), it is ready to grow and develop, to build up structures and perpetuate them, and that's what sustainability is all about. *Closing the cycle creates a stable, autonomous structure that is self-maintaining, self-renewing and self-sufficient.*

Box 34.4

Global potential of Dream Farm 2 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 %
Anaerobic digestion	
Reduced methane & nitrous oxide	3.9 %
Substituting for fossil fuel use	3.6 %
Fossil fuels saved from efficiency gains in local energy consumption	17.0 %
Total	54.0 %
Energy	
Localising food system	
Reduced transport	10.0 %
Reduced processing & packaging	3.5 %
Phasing out N fertilizers	
No fossil fuels used	3.0 %
Anaerobic digestion biogas energy	3.2 %
Fossil energies saved from efficiency gains in local energy consumption	30.0 %
Total	49.7 %

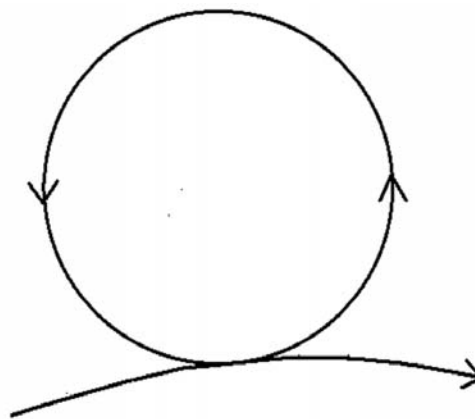


Figure 34.4. The sustainable system closes the energy and resource use cycle, maximizing storage and internal input and minimising waste, rather like the life cycle of an organism that is autonomous and self-sufficient

The technical description of the dynamic balance is the zero-entropy or zero-waste ideal (Fig. 34.5). No waste or disorganisation accumulates in the system. Even the waste exported to the outside is minimised. I emphasize that this is an ideal, and a system that attains it will never grow old or die; which is impossible; nevertheless, the closer this ideal is approached, the more the system can remain vital, as well as develop and grow [29].

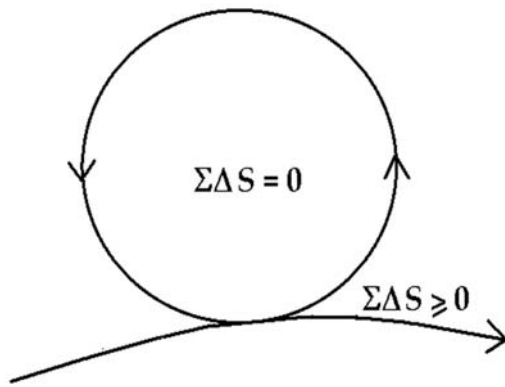


Figure 34.5. The zero-entropy model of a sustainable system

The reason the organism (and sustainable system) can approach the zero-entropy ideal is because its life cycle contains more cycles within that help one another thrive and flourish, as in the minimum integrated farm with farmer, livestock and crops (Fig. 34.6). The farmer tends the crops that feed the livestock and the farmer; the livestock returns manure to feed the crops. Very little is wasted or exported to the environment. It can perpetuate itself like this, or it can grow. The system stores energy as well as material resources such as carbon. More extra carbon is sequestered in the soil as the soil improves, and in the standing biomass of crops and livestock, which also increase as the soil-carbon increases (see Chapters 13 and 19).

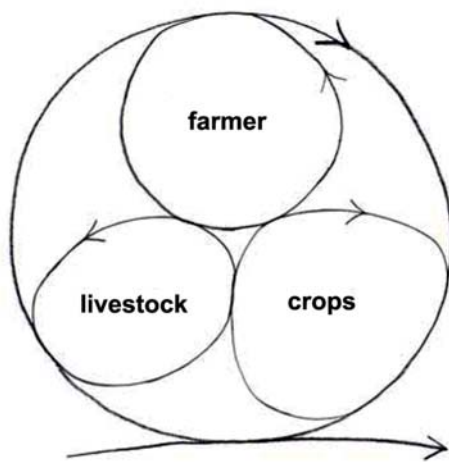


Figure 34.6. Integrated farming system that closes the cycle thereby minimizing input and waste

The system can grow by incorporating more lifecycles (yet more standing carbon stocks), more farmers or farm workers. The more lifecycles incorporated within the system, the greater the productivity (Fig. 34.7).

Productivity and biodiversity always go together in a sustainable system, as generations of farmers have known, and recent academic researchers have rediscovered (see later). It is also the most energy efficient. Why? Because the different life cycles are essentially holding the energy for the whole system by way of reciprocity, keeping as much as possible and recycling it

within the system.

Industrial monoculture, in contrast, is the least energy efficient in terms of output per unit of input, and often less productive in absolute terms despite high external inputs, because it does not close the cycle, it does not have biodiversity to hold the energy within, and it ends up generating a lot of waste and entropy and depleting the soil, thereby reducing soil fertility and food quality (see Chapter 19).

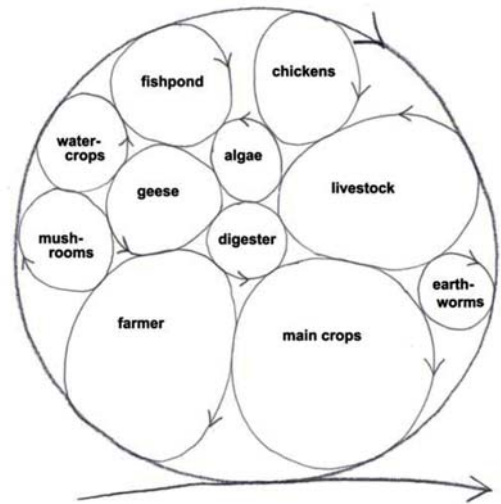


Figure 34.7. Increasing productivity by incorporating more lifecycles into the system

A more accurate representation of the interactions between different lifecycles is what I have depicted for the organism (Fig. 34.8), which shows nested, entangled cycles of activity on all scales so that the energy yielding processes are always coupled to the energy requiring processes. As one process winds down another winds up, and vice versa at a later time. This kind of reciprocity is the key to how organisms can sustain themselves, and a small amount of energy can go a long way because it can be recycled. And the more nested levels of activity, the more the energy can be recycled. The recycling of energy is a new concept, as it is generally believed that only material can be recycled. But once you realize that energy can be stored, recycling simply follows.

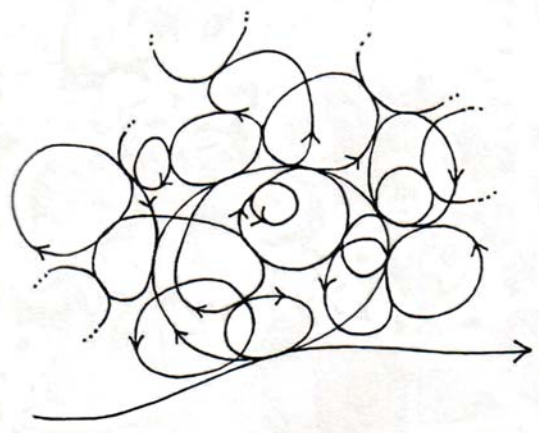


Figure 34.8. The many-fold coupled lifecycles in a highly productive sustainable system

Lessons from Dream Farm

Let me summarise what Dream Farm tells us about sustainability, which also points to areas for further research.

The importance of biodiversity and reciprocity

Dream Farm is based on biodiversity, and biodiversity is the mainstay of sustainable agriculture, as demonstrated over and over again in many chapters of this volume. Generations of indigenous farmers have always known that biodiversity means more productivity and insure against crop failures. It also happens to be nature's way of maximising the reciprocal, synergistic relationships that make species thrive better together (see especially Chapter 18). It is reciprocity and cooperation that makes the world go round, in nature as in human societies, not competition.

Academic ecologists and neo-liberal economists have been misleading policy-makers by focussing exclusively on Darwinian competition and the 'free market'. But a research team in the University of Minneapolis carried out controlled field experiments and found that bio-diverse plots are definitely more productive than monoculture plots, improving further year by year [31]. That cannot be explained by competitive interactions.

Evelyn Hutchinson, one of the greatest ecologists of the past century, posed the key question almost fifty years ago: Why are there so many species in nature? This has stumped generations of academic ecologists. The answer [32] is that the numerous species in a natural ecosystem are maximising their reciprocal relationships, storing energy and resources for one another; that is also why biodiverse, organic agroecosystems tend to be more resistant and resilient to stresses such as drought, pests and diseases (see especially Chapters 2, 13, and 18).

The myth of constant carrying capacity and the 'population crisis'

Dream Farm tells us that the carrying capacity of a piece of land is far from constant; instead it depends on the mode of production. A dream farm can be 2, 3, 10 times more productive than a monoculture farm, creating more jobs, supporting more people, as demonstrated in the circular economy of the dyke-pond system in the Pearl River Delta (see Chapter 32). The same is true of Japanese farmer Furano who supports his family of nine on two hectares, sells rice, ducks, ducklings, and provides organic vegetable boxes for 100 families (Chapter 26).

The argument for population control has been somewhat over-stated by Lester Brown of the Earth Policy Institute among others [33, 34]. In Chapter 25, we have seen how an increase in population actually provided much needed labour for greening the desert. I like the idea of "human capital" to counter the usual argument for population control. It isn't population number as such, but the glaring inequality of consumption and waste by the few rich in the richest countries that's responsible for the 'population crisis'.

Sustainable development is possible

More importantly, Dream Farm and the zero-entropy model shows that sustainable

development is possible. Sustainable development is balanced growth, achieved by closing the overall production cycle, and using the surplus nutrients and energy to support increasingly more cycles of activities while maintaining internal balance, just like a developing organism. The 'waste' from one production activity is resource for another, so productivity is maximised with minimum input, and little waste is exported to the environment.

The economic system has to generate minimum waste to be sustainable; because the waste doesn't go away, it comes back from the ecosystem into the economy. And this happens especially through the instrument of money

Critics of the neo-liberal model often say that sustainable development is an oxymoron, and the alternative is no development at all. But that is not true. Dream Farm suggests that sustainable development based on 'zero-entropy' circular economy and reciprocity is possible, and it is the alternative to the dominant model of unlimited, unsustainable growth based on competition.

Energy, entropy and money

Figure 34.9 highlights the ineluctable fact that an economic system is embedded in the ecosystem. The economic system has to generate minimum waste to be sustainable; because the waste doesn't go away, it comes back from the ecosystem into the economy. And this happens especially through the instrument of money, as I shall explain.

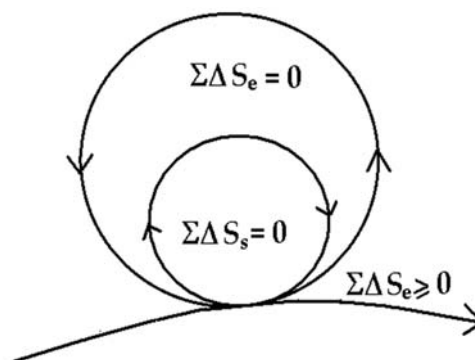


Figure 34.9. Economic system coupled to and embedded in ecosystem

The circulation of money in real world economy is often equated with energy in the living system. But all money is not equal. The flow of money can be associated with exchanges of real value or it can be associated with sheer wastage and dissipation; in the former case, money is more like energy, in the latter case, it is pure entropy or waste. When the cost of valuable (non-renewable) ecosystem resources consumed or destroyed are not properly taken into account, the waste burden falls on the ecosystem. But as the economic system is coupled to and dependent on input from the ecosystem, the waste burden exported to the ecosystem will come back into the economic system as diminished input, so the economic system becomes poorer in real terms.

Transaction in the financial or money market

creates money that is completely decoupled from real value, and is pure entropy produced within the economic system. This artificially increases purchasing power, leading to over-consumption of ecosystem resources, again impoverishing the economic system as a result.

The unequal terms of trade imposed by the rich countries of the North on the poor countries of the South through the World Trade Organisation is another important source of entropy. That too, artificially inflates the purchasing power of the North, resulting in yet more destructive exploitation of the earth's ecosystem resources in the South.

Lester Brown has called for an economy that "tells the ecological truth" [33]. But no amount of money can compensate for the earth's vital resources or resurrect a single extinct species. Rather, businesses and economies should treat ecological resources as 'natural capital', which must be replenished and restored for sustainability [35].

Localisation and wealth creation

Money also goes further when it is circulated

Dream Farm tells us that the carrying capacity of a piece of land is far from constant; instead it depends on the mode of production. A dream farm can be 2, 3, 10 times more productive than a monoculture farm, creating more jobs, supporting more people

locally, perhaps in analogy with energy storage and recycling in a system with nested cycles of activity on all scales (see Fig. 34.6). Research carried out by the New Economics Foundation has shown that money spent on a local supplier is worth four times as much as money spent on a non-local supplier [36], possibly due to money being recirculated longer within the system. It lends support to the idea of local currencies and the suggestion for linking energy with money

directly [37]. It also explains why growth in unbalanced monetary terms not only fails to bring real benefits to the nation, but end up impoverishing it in real terms [38, 39] (see also Chapters 2, 3, 4 and 22). This is an exciting area for further research.

Dream farms coming to your neighbourhood soon

ISIS is currently developing an implementation/planning model for Dream Farm 2, in collaboration with the Third World Network and other organisations, which can be adapted to a farm of any size, anywhere in the world. It will compute projected costs and benefits, not only in financial terms, but especially also in terms of savings in energy and carbon emissions (including carbon sequestered in the soil and in standing biomass). We also intend to help transfer appropriate technologies for mitigating climate change to Third World countries at no cost. We believe this is the best way forward to a greener, cleaner, healthier and more fulfilling life for all, free from fossil fuels [13].

We need something like Dream Farm 2 not only to feed the world, or to mitigate climate change, or to avert the energy crisis. Yes, it is all of those and more. We need to prevent false solutions such as nuclear power plants and genetically modified crops foisted on us. Most important of all, we need to mobilise human ingenuity and creativity, to make us go on dreaming and working for a better world.



References

All Science in Society articles cited can be found at:

<http://www.i-sis.org.uk/onlinestore/magazines.php>

Preface

1. Ho MW, Bunyard P, Saunders PT, Bravo E and Gala R. *Which Energy?* 2006 ISIS Energy Report, Institute of Science in Society, London, 2006.

Chapter 1

1. Dyer G. How long can the world feed itself? *Energy Bulletin*, 10 October 2006, <http://www.energybulletin.net/21736.html>
2. Economic Briefing, National Association of British and Irish Millers, August 2007, http://www.nabim.org.uk/ecoBrief07_8.asp
3. Brown L. *Plan B: Rescuing a Planet under Stress and a Civilization in Trouble*, Earth Policy Institute, W.W. Norton & Company, New York, 2003.
4. Ho MW. Is oil running out? *Science in Society* 2005, 25, 50-51.
5. Darley J. High Noon for Natural Gas, Chelsea Green Publishing Company, Vermont, 2004.
6. "Steep decline in oil production brings risk of war and unrest, says new study" Ashley Seager, *TheGuardian* 22 October 2007, <http://www.guardian.co.uk/oil/story/0,,2196435,00.html>
7. *Yield Response to Water*, FAO, Rome, 1979, cited in Brown, 2003.
8. Günther F. Vulnerability in agriculture: energy use, structure and energy futures. Paper presented at the INES conference, KTH Stockholm, 15 June 2000 <http://etnhum.etn.lu.se/~fg/written/stuff/ines/INES.pdf>
9. Hall CAS, Cleveland CJ and Kaufmann R. *Energy and Resource Quality*, Wiley Interscience, New York, 1986.
10. *Empty Breadbasket? The Coming Challenge to America's Food Supply and What We Can Do About It*. The Cornucopia Project. Rodale Press, Emmaus, PA, 1981.
11. Pimental D, Armstrong L, Flass C, Hopf F, Landy R and Pimentel M. Interdependence of food and natural resources. Food and Natural Resources (Pimentel D and Hall C, eds), Academic Press, San Diego, 1989.
12. Voeding, Milieu en budget, report by Milieucentraal and Nibud, Utrecht, 2001.
13. Pirog R.. "Checking the Food Odometer: Comparing Food Miles for Local Versus Conventional Produce Sales in Iowa Institutions." Leopold Center for Sustainable Agriculture. July 2003.
14. Caroline Lucas MEP "Stopping the Great Food Swap" (speech) based on background research and support provided by Andy Jones and Vicki Hird of Sustain: The alliance for better food and farming, and by Colin Hines, author of Localisation: A Global Manifesto, Earthscan 2000.
15. Hines C, Lucas C and Shiva V. Local food, global solution. *The Ecologist*, vol 32 No 5 June 2002 p 38.
16. Increased Greenhouse Gas Emissions, FAO, <http://lead.virtualcentre.org/zh/dec/toolbox/indust/ghgas.html>
17. How much greenhouse gases in our plate? Jean-Marc Jancovici. March 2004 http://www.manicore.com/anglais/documentation_a/greenhouse/plate.html
18. Trading away the right to food, Oxfam Canada, <http://www.oxfam.ca/news-and-publications/educational-resources/presentations/trading-away-the-right-to-food-1/?searchterm=Trading%20away%20the%20right%20to%20food>
19. "Farming support: the truth behind the numbers" by Stefan Tangermann, Director OECD Food, Agriculture and fisheries Directorate March 2004 http://www.oecdobserver.org/news/printpage.php/aid/1223/Farming_support:_the_truth_behind_the_numbers.html
20. Ho MW. Global warming is happening. *Science in Society* 2006, 31, 23-24.
21. Ho MW. Abrupt climate change happening. *Science in Society* 2003, 20, 23-24.
22. Peng S, Huang J, Sheehy JE, LazAa RC, Vesperas RM, Zhong X, Centeno GS, Khush GS and Cassman KG, Rice yields decline with higher night temperatures from global warming. *PNAS* 2004, 101, 9971-5.
23. "Climate change boosting flood and drought: experts" News in Science, ABC, 3 March 2003, <http://www.abc.net.au/science/news/stories/s796319.htm>
24. "Special report: from words to action", *Nature News* 2007, 445, 578-9.
25. Canadell JG, Le Quéré C, Raupach MR, Field CB, Buitenhuis ET, Ciais P, Conway TJ, Gillett NP, Houghton RA and Marland G. Contributions to accelerating atmospheric CO₂ growth from economic activity, carbon intensity, and efficiency of natural sinks. *PNAS Early Edition*, 2007, www.pnas.org/cgi/doi/10.1073/pnas.07273104
26. "Scientists fear climate change speed-up as oceans fail to hold greenhouse gases", Andrew Woodcock, *The Scotsman*, 21 October 2007, <http://news.scotsman.com/scitech.cfm?id=1678172007>; Schuster U and Watson AJ. A variable and decreasing sink for atmospheric CO₂ in the North Atlantic, preprint, courtesy of authors.
27. Ho MW. Oceans carbon sink or source. *Science in Society* 2006, 31, 14.
28. Energy use in organic farming systems. MAFF project OFO182 (1996/2000)
29. Lal R. Soil carbon sequestration impacts on global climate change and food security. *Science* 2004, 304, 1623-7.
30. Wood S and Cowie A. A review of greenhouse gas emission factors for fertiliser production. For IEA Bioenergy Task 38 June 2004. http://www.joanneum.ac.at/iea-bioenergytask38/publications/GHG_Emission_Fertilizer%20Production_July2004.pdf
31. Lasco RD, Sales RF, Extrella R, Saplaco SR, Castillo ASA, Cruz RVO ad Pulhin FB. Carbon Stock Assessment of Two Agroforestry Systems in a Tropical Forest Reserve in the Philippines. *The Philippine Agriculturist* 2001, 84, 401-7.
32. Schroeder P. Agroforestry system: integrated land use to store and conserve carbon. *Climate Research* 1993, 3, 53-60
33. Ho MW. Dream farm. *Science in Society* 2005, 27, 26-28.
34. Ho MW. Biogas bonanza for third world development. *Science in Society* 27, 28-29, 2005.
35. Edwards S. Greening Ethiopia series, *Science in Society* 2004, 23, 4-8.

36. Delate K, and Cambardella, CA. Organic Production. Agroecosystem performance during transition to certified organic grain production. *Agronomy Journal* 2004, 96:1288-1298.
37. Lim LC. Organic agriculture fights back. *Science in Society* 2002, 16, 30-32.
38. 100-Year Drought Is No Match for Organic Soybeans, Rodale Institute, 1999.
http://www.rodaleinstitute.org/global/arch_home.html
39. "Report proves that organic farming is better for wildlife" Soil Association Press Release 7 October 2004.
40. Worthington V. Nutrition quality of organic versus conventional fruits, vegetables and grains. *The Journal of Alternative and Complementary Medicine* 2001, 7, 161-73.
41. Lim LC. Organics for health. *Science in Society* 2003, 19, 29.
42. Heaton S. Organic farming, food quality and human health: A review of the evidence. Soil Association, Bristol 2001.
43. Cummins J. Organic agriculture helps fight cancer. *Science in Society* 2003, 18, 18.
44. "More crops for Africa as trees reclaim the desert", Andy Coghlan, *New Scientist*, 14 October 2006, 192, 11.
45. Hepperly P. Organic farming sequesters atmospheric carbon and nutrients in soils. The Rodale Institute, Pennsylvania, USA, 15 October 2003, http://www.newfarm.org/depts/NFfield_trials/1003/carbonwhitepaper.shtml
46. Pretty J. *Agri-Culture, Reconnecting People, Land and Nature*, Earthscan, London, 2002.
47. Boyde T. Cusgarne Organics local money flows. New Economics foundation and the Countryside Agency, London, 2001.
48. "Buying local worth 400 per cent more" New economics foundation 07.03.05
http://www.neweconomics.org/gen/news_buyinglocalworth400percentmore.aspx
49. Ho MW, Novotny E, Webber P and Daniels EE. Towards a Convention on Knowledge, Draft 7, ISIS-SGR-TWN Discussion Paper, ISIS, 2001, <http://www.i-sis.org.uk/conventiononknowledge.php>
50. Pimbert M. Transforming Knowledge and Ways of Knowing for Food Sovereignty, Reclaiming Diversity & Citizenship Series, iied, International Institute for Environment and Development, London, 2006.

Chapter 2

1. "Watson book tour cancelled after racism claims", Sally Peck, Telegraph.co.uk, 20 October 2007, <http://www.telegraph.co.uk/news/main.jhtml?xml=/news/2007/10/19/nwatson119.xml>
2. "DNA pioneer quits after race comments", Thomas H. Maugh, latimes.com, 26 October 2007, <http://www.latimes.com/news/nationworld/world/la-sci-watson26oct26,1,7818665.story?coll=la-headlines-world&ctrack=1&cset=true>
3. Ho MW. Why genomics won't deliver. *Science in Society* 2005, 26, 39-42.
4. Ho MW. *Living with the Fluid Genome*, ISIS and TWN, London and Penang, 2003.
5. Ho MW. Life beyond the Central Dogma series. *Science in Society* 24, 4-13, 2004.
6. Borlaug N. Feeding a hungry world. Editorial, *Science* 2007, 318, 359.
7. "WFP Founder Norman Borlaug receives America's highest civilian honor", The World Food Prize, 18 July 2007, http://www.worldfoodprize.org/press_room/2006/december/borlaug-congressional.htm
8. Rosset P, Collins J and Moore Lappe V. Lessons from the Green Revolution, Food First/Institute for Food and Development Policy, 2000, <http://www.foodfirst.org/media/opeds/2000/4-greenrev.html>
9. "Time for an 'ever-green' revolution: Prof. Swaminathan", The World Today, 20 September 2004, ABC, Australia, <http://www.abc.net.au/worldtoday/content/2004/s1209692.htm>
10. Tacio H. Feeding a world of 9 billion 1 October 2007, <http://www.peopleandplanet.net/doc.php?id=341§ion=3>
11. Holt-Gimenez E, Altieri MA and Rosset P. Ten Reasons Why the Rockefeller and the Bill and Melinda Gates Foundations' Alliance for Another Green Revolution Will Not Solve the Problems of Poverty and Hunger in Sub-Saharan Africa. Food First Policy Brief No. 12, October 2006
12. "One suicide every 8 hours", Jaideep Hardikar, 26 August 2006, DNA, India, <http://www.dnaindia.com/report.asp?NewsID=1049554>
13. Ho MW. Philanthropy Gates' style. *Science in Society* 2007, 35, 4-8.
14. Ho MW. The Golden Rice - An Exercise in How Not to Do Science, TWN-ISIS Report, 2000, <http://www.i-sis.org.uk/rice.php>
15. Ho MW. Organic farmer who value his freedom above all. *Science in Society* 28, 11-12, 2005.
16. Ho MW, Cummins J. et al. *GM Science Exposed, Hazards Ignored, Fraud, Regulatory Sham, Violation of Farmers' Rights*, ISIS CD Book, 2007.
17. Ho MW and Lim LC. The Case for a GM-Free Sustainable World, Independent Science Panel Report, Institute of Science in Society and Third World Network, London and Penang, 2003; republished *GM-Free, Exposing the Hazards of Biotechnology to Ensure the Integrity of Our Food Supply*, Vitalhealth Publishing, Ridgefield, Ct., 2004 (both available from ISIS online bookstore <http://www.i-sis.org.uk/onlinestore/books.php#1>
18. Murphy C. Cultivating Havana: Urban Agriculture and Food Security in the Years of Crisis, May 1999, www.Foodfirst.org
19. Ho MW. Exploding the food myths in the GM debate. ISIS News 5, July 2000.
20. Wright J. *Falta Petroleo! Perspectives on the emergence of a more ecological farming and food system in post-crisis cuba*, Wageningen UR 2005 ISBN: 90-8504-197-X
21. Pimbert M. Transforming Knowledge and Ways of Knowing for Food Sovereignty, Reclaiming Diversity & Citizenship Series, iied, International Institute for Environment and Development, London, 2006.

Chapter 3

1. Ho MW and Lim LC. *The Case for a GM-Free Sustainable World*, Independent Science Panel Report, Institute of Science in Society and Third World Network, London and Penang, 2003; republished *GM-Free, Exposing the Hazards of Biotechnology to Ensure the Integrity of Our Food Supply*, Vitalhealth Publishing, Ridgefield, Ct., 2004 (both available from ISIS online bookstore <http://www.i-sis.org.uk/onlinestore/books.php#1>)
2. Ho MW, Cummins J and Saunders PT. GM nightmare unfolding in the regulatory sham. *Microbial Ecology in Health and Disease* 2007, 19, 66-77.
3. Ho MW. No to GMOs, no to GM science. *Science in Society* 2007, 35, 26-29
4. Ho MW. Schmeiser's battle for the seed. *Science in Society* 2003, 19, 13-14.
5. Burcher S. Monsanto versus farmers. *Science in Society* 2005, 26, 33-48.
6. Ho MW and Saunders PT. The beginning of the end for patents on GM crops? From the Editors, *Science in Society* 2007, 35, 3.

Chapter 4

1. Lucas C. Local Food: The global solution. 9 Jul 2001. www.carolinelucasmep.org.uk/speeches/localfood_09072001.html
2. CAP reforms fudge real issues behind farming exodus. 12 Feb 2004. www.farm.org.uk/FM_Content.aspx?action=detail&id=169
3. Kwa A. EU's CAP "Reform"? Let us not be fooled. 26 Jun 2003. www.twinside.org.sg/title/capreform.doc
4. Woollacott M. Special Report: The countryside in crisis. Farmers learn the lie of the land. *Guardian*. Friday, March 2, 2001. www.guardian.co.uk/comment/story/0,3604,445166,00.html
5. Hassebrook C. A time to act for family sized farms. 1998.
6. <http://ianrwww.unl.edu/ianr/csas/abstrF98.htm>
7. More farmers leaving the land. CBC News. 15 May 2002. www.cbc.ca/stories/2002/05/15/farms_020515
8. Manifesto on the future of food. International Commission on the Future of Food and Agriculture. 15 Jul 2003. www.farmingsolutions.org/pdfdb/manifestoinglese.pdf
9. Murphy S. WTO Agreement on Agriculture: Suitable Model for a Global Food System? Institute for Agriculture and Trade Policy. Foreign Policy In Focus v.7, n.8, Jun 2002. www.mindfully.org/WTO/Agreement-On-Agriculture-FPIFJun02.htm
10. Pretty J, N Brett C, Gee D, Hine RE, Mason CF, Morison JIL, Raven H, Rayment MD, Van der Bijl G., An assessment of the total external costs of UK agriculture, *Agricultural Systems* (65)2 (2000) pp. 113-136, UK, 2000. Cited in
11. Lucas C. Stopping the great food swap - Relocalising Europe's food supply. www.carolinelucasmep.org.uk/framesets/publications.html
12. 2005 and sustainable development: Why the UK government is part of the problem. Report by World Development Movement, War on Want, Friends of the Earth, National Union of Students. 2005, http://www.wdmscotland.org.uk/media/campaigns/g8/uk_&_sust_dev.pdf
13. Murphy S. Structural distortions in world agricultural markets: Do WTO rules support sustainable agriculture? *Columbia Journal of Environmental Laws* 2002, 27.
14. Einarsson P. The disagreement on agriculture. Mar 2001. <http://www.grain.org/seedling/?id=145>
15. Income, Gaps in income and wealth remain large, National Statistics, 7 December 2004, <http://www.statistics.gov.uk/cci/nugget.asp?id=1005>
16. Common organization of the agricultural markets/ Reforms and reviews of the Common Agricultural Policy. Jun 2003. www.europa.eu.int/scadplus/leg/en/lvb/l11089.htm
17. Clarke P 'Farming to follow the dinosaurs' *Farmers Weekly*. 5 Nov 2003. <http://www.fwi.co.uk/article.asp?con=12848&sec=208&hier=263&email=1>
18. CAFOD slams CAP reform for failing the Third World. 26 Jun 2003. www.twinside.org.sg/title/capreform.doc
19. Bennett, R. et al. Economic evaluation of farm animal welfare policy. Department of Agricultural and Food Economics, University of Reading. December 2000. Final Report to MAFF. Eurostat data. Cited in Lucas C. Stopping the great food swap -Relocalising Europe's food supply. www.carolinelucasmep.org.uk/framesets/publications.html
20. Lobstein, T, and Hoskins, R, The Perfect Pinta Food Facts No. 2. The SAFE Alliance, 1998. Cited in Lucas C. Stopping the great food swap - Relocalising Europe's food supply. <http://www.carolinelucasmep.org.uk/framesets/publications.html>
21. Food miles - still on the run. Sustain, 1999. Cited in Lucas C. Stopping the great food swap - Relocalising Europe's food supply. www.carolinelucasmep.org.uk/framesets/publications.html
22. Ray DE, De la Torre Ugarte DG, Tiller KG. Rethinking US agricultural policy: Changing course to secure farmer livelihoods worldwide. *Agricultural Policy Analysis Center*. University of Tennessee. 2003. www.farmingsolutions.org/pdfdb/RAP.pdf
23. Kloppenberg J. *First the seed: The political economy of plant biotechnology*. New York: *Cambridge University Press* 1988.
24. Horrigan L, Lawrence RS, Walker P. How sustainable agriculture can address the environmental and human health harms of industrial agriculture. Center for a Livable Future, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA. *Environmental Health Perspectives: Research Review*, Vol 110: 5, 445-456, May 2002.
25. WTO Agreement on Agriculture: A decade of dumping. Institute for agriculture and trade policy. Press release Feb 9 2005. www.iatp.org
26. Help Farmers, Help the Environment - Fix Farm Subsidies. 2005. www.actionnetwork.org/campaign/farmbill2
27. Kicking down the door, Oxfam Briefing Paper. April 2005 41 www.farmingsolutions.org/pdfdb/bp72_rice.pdf
28. Food aid or hidden dumping, separating wheat from chaff. Oxfam briefing paper. March 2005. www.farmingsolutions.org/pdfdb/oxfamreportUS.pdf
29. Planting the rights seed: A human rights perspective on agricultural trade and the WTO. Institute for agriculture and trade policy. Press release Mar 18 2005. www.iatp.org
30. Pretty J, Hine R. Feeding the world with sustainable agriculture: A summary of new evidence. SAFE World Research Project, University of Essex 2000. Cited in Lucas C. Stopping the great food swap - Relocalising Europe's food supply. www.carolinelucasmep.org.uk/framesets/publications.html

31. Altieri M. Agroecology versus ecoagriculture. *Science in Society* 2005, 25, 17-20.
32. Pretty J. The true cost of intensive farming. Living Earth, Bristol. Soil Association 208 October - December 2000. Cited in Local Food: The global solution. www.carolinelucasmep.org.uk/speeches/localfood_09072001.html

Chapter 5

2. Ho MW. Biofuels for oil addicts, cure worse than the addiction? *Science in Society* 2006, 30, 29-30.
3. Perlack RD, Wright LL, Turhollow AF, Graham RL, Stokes BJ, Erback DC. *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, US Department of Energy and Department of Agriculture, April 2005.
4. Biodiesel Project Development, Biofuels Corporation plc, April 2006, <http://www.biofuelscorp.com/project.html>
5. Important notice, Biofuels Corporation, accessed 14 October 2007, <http://www.biofuelscorp.com/>
6. Directive 2003/30/EC, http://europa.eu.int/comm/energy/res/legislation/biofuels_en.htm
7. Ho MW. Biodiesel boom in Europe? *Science in Society* 2006, 30, 31-32. <http://www.i-sis.org.uk/onlinestore/magazines.php>
8. "EP demands sustainability certification for biofuels", 27 September, 2007, AutoblogGreen, <http://www.autobloggreen.com/2007/09/27/european-parliament-demands-sustainability-certification-fo/>
9. International Energy Authority, Biofuels for Transport: An International Perspective, IEA, Paris, 2004. <http://www.iea.org/textbase/nppdf/free/2004/biofuels2004.pdf>
10. NTB Liquid Biofuels Network - The European Network for removing non-technical barriers to the development of liquid biofuels, 29 September 2006, <http://www.biomatnet.org/secure/Ec/S1016.htm>
11. "EU suspends set-aside" Liberal Democrat MEPs in the European Parliament, 26 September 2007, http://www.libdemmps.org.uk/news/000391/eu_suspends_setaside.html
12. "Energy and greenhouse gas balance for Europe - an update" by CONCAWE ad hoc group on Alternative Fuels, Report 2/02. Source: http://www.senternovem.nl/mmfiles/26601_tcm24-124161.pdf
13. Kavolov B. *Biofuel Potentials in the EU*, Technical Report Series, EU21012EN, Institute for Prospective Technological Studies, European Commission Joint Research Centre, January 2004.
14. Communique issued at the end of a Regional Conference on Biosafety, Abuja, November 27-29, 2006, Environment rights Action/ Friend of the Earth Nigeria, www.eraction.org
15. Ho MW. Making the world GM free and sustainable. Weston A. Price Foundation Wise Tradition Keynote Lecture, 11 November 2006.
16. UKERC Energy Research Atlas: Bioenergy, 2006, http://ukerc.rl.ac.uk/Landscapes/Bioenergy_Section1.pdf
17. "Food crisis feared as fertile land runs out", *Guardian unlimited*, 6 December 2005, <http://www.guardian.co.uk/food/Story/0,,1659112,00.html>
18. Ho MW. Sustainable food system for sustainable development. *Science in Society* 2005, 27, 33-35.
19. Zhou G, Liu S, Li Z, Zhang D, Tang X, Zhou C, Yan J and Mo J. Old-growth forests can accumulate carbon in soils. *Science* 2006, 314, 1417.
20. Ho MW. Biofuels Republic Brazil. *Science in Society* 33, 40-41.
21. *The Oil for Ape Scandal, How Palm Oil is Threatening the Orang-utan*, Friends of the Earth Report, 2005.
22. Palm oil: deforestation diesel? New Agriculturist online, 1 November 2006, <http://www.new-agri.co.uk/06-6/focuson/focuson6.html>
23. Butler RA. High oil prices fuel bioenergy push, Mongabay.com, 9 May 2006, <http://news.mongabay.com/2006/0509-biofuels.html>
24. Unilever's contribution to Review of EU Biofuels directive Public consultation exercise, April-July 2006, Energy and Transport Directorate-General, European Commission, <http://ec.europa.eu/energy/res/legislation/doc/biofuels/contributions/industry/unilever.pdf>
25. "Asia corn buyers in desperate search for supply", Daily Times, Pakistan, 3 December 2006, http://www.dailytimes.com.pk/default.asp?page=2006%5C12%5C03%5Cstory_3-12-2006_pg5_30
26. "Now bread, cereal prices may go up like bananas", thewest.com.au, 11 October 2006, <http://www.thewest.com.au/default.aspx?MenuID=31&ContentID=9319>
27. "Wheat prices jump to record high", Javier Blas, FT.com 23 August 2007, <http://www.ft.com/cms/s/0/9939d268-51b8-11dc-8779-0000779fd2ac.html>
28. Ho MW. Ethanol from cellulose biomass not sustainable nor environmentally benign. *Science in Society* 2006, 30, 32-35.
29. DeNocker L and Spirinckx C. Comparison of LCA and external-cost analysis for biodiesel and diesel. Paper presented at DPA-sponsored International Conference and Exhibition on Life Cycle Assessment, 25-27 April 2000, cited by Van Gerpen JV. Analysis of "Comparative LCA of biodiesel and fossil diesel fuel" by Ceuterick and Spirinckx. 7 July 2000. http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20000707_gen-280.pdf
30. Richards IR. Energy balances in the growth of oilseed rape for biodiesel and of wheat for bioethanol. Levington Agriculture Report, British Association for Bio Fuels and Oils, 2000, <http://www.biodiesel.co.uk/levington.htm#3.%20Crop%20production%20and%20energy%20output>
31. "New finding: organic farming combats global warming...big time", Laura Sayre, The New Farm, January 2008, http://www.newfarm.org:80/depts/NFfield_trials/1003/carbonsequest.shtml
32. Beer T, Grant T, Morgan G, Lapszewicz J, Anyon P, Edwards J, Nelson P, Watson H, and Williams D. Comparison of Transport Fuels. Final report (EV45A/2/F3C) to the Australian Greenhouse Office on the Stage 2 study of, Life-cycle emissions analysis of alternative fuels for heavy vehicles. http://www.cmar.csiro.au/e-print/open/beer_2001a.pdf
33. Sheehan J, Camobreco V, Duffield J, Graboski M and Shapouri H. *Life Cycle Inventory of Biodiesel and Petroleum Diesel for Use in an Urban Bus*, A Joins Study Sponsored by: U.S. Department of Agriculture and U.S. Department of Energy, final Report, May 1998. <http://www.nrel.gov/docs/legosti/fy98/24089.pdf>
34. Pimentel D and Patzek TW. Ethanol production using corn, switchgrass and wood; biodiesel production using soybean and sunflower. *Natural Resources Research* 2005, 14, 65-76.

35. Farrell AE, Plevin RJ, Turner BT, Jones AD, O'Hare M and Kammen DM. Ethanol can contribute to energy and environmental goals. *Science* 2006, 311, 506-8.
36. Smeets E, Hunginger M, Faaij A, Walter A, Dolzan P. Sustainability of Brazilian bio-ethanol., Report NWS-E-2005-110, ISBN 90-8672-012-9 August 2006.
37. "Two killed at protest against GM seed farm", John Vidal, 23 October, *The Guardian*, <http://www.guardian.co.uk/international/story/0,,2197018,00.html>
38. "Brazilian ethanol is sustainable and has a very positive energy balance - IEA report." 8 October 2006, BioPact Towards a green energy pact between Europe and Africa, <http://biopact.com/2006/10/brazilian-ethanol-is-sustainable-and.html>
39. Ernsting A. Biofuels: Renewable energy or environmental disaster in the making, Biofuelwatch, 2006, <http://www.biofuelwatch.org.uk/background.php>
40. Strydom L. Growing biofuel. A biodiesel entrepreneur's checklist for anyone considering entering this infant industry. *Ecoworld* 26 April, 2006, <http://www.ecoworld.com/home/articles2.cfm?tid=387>
41. Ho MW. Jatropha biodiesel fever in India. *Science in Society* 2007, 36, 47-48.
42. Righelato R and Spracklen DV. Carbon mitigation by biofuels or by saving and restoring forests? *Science* 2007, 317, 902.
43. Stern Review on the Economics of Climate Change, HM Treasury, 2007, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm
44. Saunders PT. The economics of climate change. *Science in Society* 2007, 33, 20-23.
45. Ho MW, Bunyard P, Saunders PT, Bravo E and Gala R. *Which Energy?* 2006 ISIS Energy Report, Institute of Science in Society, London, 2006.
46. Li K-H, and Ho MW. Biogas China. *Science in Society* 2006. 32, 34-37.
47. Ho MW. Biogas bonanza for Third World Development. *Science in Society* 2005, 27, 29.

Chapter 6

1. "Crop diversity vital to world's ag", Hembree Brandon, Southwest Farm Press 2 June 2005, http://southwestfarmpress.com/mag/farming_crop_diversity_vital_2/
2. "Maize in global gene bank crisis", New Scientist, 15 May 2006, <http://www.newscientist.com/channel/life/genetics/mg19025513.200-maize-in-global-gene-bank-crisis.html>
3. "Gene Banks Help Maintain Global Biodiversity, U.N Official Says, October 19, 2004" 20 October 2004 <http://usunrome.usembassy.it/UNIssues/biotech/docs/a4102002.htm>
4. "Lack of cash puts gene banks in jeopardy" *Guardian* Newspapers 29 August 2002. <http://www.buzzle.com/editorials/8-29-2002-25462.asp>
5. Start with a Seed. <http://www.startwithaseed.org/items/trust.php>
6. "Gene-banks: fund them or lose them" *New Agriculturist* on-line, 1 January 2005. <http://www.new-agri.co.uk/05-1/develop/dev03.html>
7. Perrino P. Italy's genebank at risk. *Science in Society* 2005, 27, 47-48.
8. Tanksley SD and McCouch SR. Seed banks and molecular maps: unlocking genetic potential from the wild. *Science* 1997, 277, 1063-66.
9. Burcher S. Monsanto versus Farmers. *Science in Society* 2005, 26, 33-48.
10. Ho MW. Science for the poor, or procurer for the rich? *Science in Society* 2002, 15, 8.

Chapter 7

1. Sligh M and Christman C. Who Owns Organic? The Global Status, Prospects, and Challenges of a Changing Organic Market. 2003, Rural Advancement Foundation International-USA, Pittsboro, NC <http://rafiusa.org/pubs/OrganicReport.pdf>
2. The World of Organic Agriculture: Statistics and Emerging Trends 2007, IFOAM, http://www.ifoam.org/press/press/Statistics_2007.html
3. Organic Inc. Jason Mark, San Francisco Chronicle, 9 June 2005 <http://www.sfgate.com/cgi-bin/article.cgi?file=/chronicle/archive/2005/06/09/EDGISD5JL61.DTL>

Chapter 8

1. *The Validity of Food Miles as an Indicator of Sustainable Development* Final Report produced for DEFRA by AEA Technology, July 2005.
2. "Organic not organic if it's air-freighted, says Soil Association", Jess Halliday, Food&Drink Europe.com, 25 October 2007, <http://www.foodanddrinkeurope.com/news/ng.asp?n=80867-soil-association-organic-air-freight>
3. "The Soil Association Standards Board recommendations following the air freight consultation", The Soil Association, October 2007, <http://www.soilassociation.org/airfreight>
4. "Oxfam welcomes Soil Association announcement on organic certification", Oxfam, 25 October 2007, http://www.oxfam.org.uk/applications/blogs/pressoffice/2007/10/oxfam_welcomes_soil_associatio.html
5. "Gareth Thomas responds to Soil Association decision on air-freighted products", DFID News, 26 October 2007, <http://www.dfid.gov.uk/news/files/soil-association.asp>
6. Final Submission of the Food Industry Sustainability Strategy Champions' Group on Energy and Climate Change, May 2007, DEFRA, <http://www.defra.gov.uk/farm/policy/sustain/fiss/pdf/report-climate-change-may2007.pdf>
7. "Balancing the cost of food air miles: Listening to trade and environmental concerns", DFID News, 17 September 2007, <http://www.dfid.gov.uk/news/files/foodmiles.asp>
8. *Challenges and Implications Arising from the Achievement of CAMC's 2005 Agri-Food Export Target*, Appendix A: Prospects for Agri-Food Trade Growth, Agriculture and Agri-Food Canada, 27 July, 2006, http://www.agr.gc.ca/pol/index_e.php?s1=pub&s2=camc-2005-cccpa&page=app-a-ann

9. Pimbert M. Supporting locally determined food systems: the role of local organizations in farming, environment and people's access to food. In *How to Make Poverty History, The central role of local organizations in meeting the MDGs* (Bigg T and Satterthwaite D eds), pp. 129- 155, iied, International Institute for Environment and Development, London, 2005.
10. Porrata-Maury C, Abuin-Landin A, Morales-Zayas A, Vilá-Dacosta-Calheiros R, Hernández-Triana M, Menéndez-Hernández J, Diaz-Sanchez ME, Mirabal-Sosa, Campa-Huergo C, Pianesi M. Efecto terapéutico de la dieta macrobiótica Ma-Pi en 25 adultos con diabetes mellitus tipo 2. *Rev Cubana Invest Biomed* 1007, 26(2).

Chapter 9

1. Badgley C, Moghtader J, Quintero E, Zakem E, Chappell M.H. Aviles-Vazquez K, Salon A and Perfecto I. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems* 2007, 22 (2), 86-108.
2. Pimental D, Hepperly P, Hanson J, Doubs D and Seidel R. Environmental, energetic, and economic comparisons of organic and conventional farming systems. *BioScience* 2005, 55, 573-82.
3. Ho MW and Lim LC. *The Case for a GM-Free Sustainable World*, Independent Science Panel Report, Institute of Science in Society and Third World Network, London and Penang, 2003; republished *GM-Free, Exposing the Hazards of Biotechnology to Ensure the Integrity of Our Food Supply*, Vitalhealth Publishing, Ridgefield, Ct., 2004 (both available from ISIS online bookstore <http://www.i-sis.org.uk/onlinestore/books.php#1>)
4. Ho MW, Bunyard P, Saunders PT, Bravo E and Gala R. *Which Energy?* 2006 ISIS Energy Report, Institute of Science in Society, London, 2006. <http://www.i-sis.org.uk/onlinestore/books.php#238>
5. Manifesto On the Future of Food, the International Commission on the Future of Food and Agriculture, San Rossore, a New Global Vision, Tuscany, Italy, 2003.

Chapter 10

1. International conference on organic agriculture and food security Rome 3-6 May 2007 Report <ftp://ftp.fao.org/docrep/fao/meeting/012/J9918E.pdf>
2. World Food Summit for All. Rome 13-17 Nov 1996 <http://www.fao.org/DOCREP/x0262e/x0262e05.htm>
3. Halsberg, N. Alroe, HF, Knudsen, MT, and Kristensen, E.S. (eds) 2006, Global development of organic agriculture challenges and promises. Wallingford: CABI Publishing
4. Badgley C, Moghtader J, Quintero E, Zakem E, Chappell M.H. Aviles-Vazquez K, Salon A and Perfecto I. Organic agriculture and the global food supply. *Renewable Agriculture and Food Systems* 2007, 22 (2), 86-108.
5. "Can growers make more money by going organic? Don Comis, 25 July 2006 www.ars.usda.gov/is/pr/2005/060725.htm, via <http://organicecology.umn.edu/wp-content/files/growersmoremoney.pdf>
6. Wright J. *Falta Petroleo! Perspectives on the emergence of a more ecological farming and food system in post-crisis Cuba 2005*, Wageningen/HDRA
7. Ho MW and Gala R. Food Miles and Sustainability. *Science in Society* 2005, 28, 38-39.
8. Soil Association (2001) Organic farming, food quality and human health: a review of the evidence.
9. Worthington V. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *Journal of Complementary Medicine* 2001, 7, 2:161-173.48.
10. Soil Association Information Sheet, Organic farming and the environment www.soilassociation.org/web/sa/saweb.nsf/printable_library/NT00010B6
11. Sir John Krebs, Chair, Food Standards Agency, Cheltenham Science Festival debate, 5th June 2003.
12. BMA (1992) The BMA guide to pesticides, chemicals and health. Report of the Board of Science and Education, British Medical Association.
13. Eskenazi B, Bradman A, and Castorina R. Exposure of children to organophosphates pesticides and the potential adverse health effects. *Environmental Health Perspectives* 2003, 111, 3:409-418.
14. Charlier G, et al Breast cancer and serum organochloride residues *Occupational and Environmental Health Perspectives* 2003 60 5:348-351.
15. Curl CL Fenske and Elgethun K. Organophosphorus pesticide exposure of urban and suburban pre-school children with organic and conventional diets, *Environmental Health Perspectives* 2003, 111 3:379-382.
16. Halweil, B. Can organic farming feed the world? *Worldwatch Magazine* May-June 2006 Worldwatch Institute.
17. Cassman K. Editorial response by Kenneth Cassman: can organic agriculture feed the world-science to the rescue? *Renewable Agriculture and Food Systems* 2007, 22(2): 80-85

Chapter 11

1. Ethiopian Mapping Authority. *National Atlas of Ethiopia*. Ethiopian Mapping Authority, Addis Ababa, 1988.
2. Gemechu D. *Aspects of Climate and Water Budget in Ethiopia*, Addis Abeba University Press, 1977.
3. Engels JMM, Hawkes JG and Melaku W eds. *Plant Genetic Resources of Ethiopia*. Cambridge Univ. Press, Cambridge, 1991.
4. Edwards S. Crops with wild relatives found in Ethiopia. In: Engels JMM, Hawkes JG and Melaku W eds. *Plant Genetic Resources of Ethiopia*. Cambridge Univ. Press, Cambridge, 1991.
5. EPA. *The Federal Democratic Republic of Ethiopia - State of Environment Report for Ethiopia*. August, 2003. Environmental Protection Authority (EPA), Addis Ababa, 2003.
6. Ministry of Finance and Economic Development (MoFED). Ethiopia: Building on Progress. A Plan for Accelerated and Sustained Development to End Poverty (PASDEP) (2005/06-2009/10), Volume I: Main Text. MoFED, Addis Ababa, 2006.
7. Sasakawa-Global 2000 Programme, <http://www.saa-tokyo.org/english/sg2000/>
8. Asfaw A. The Current Depressed Cereal Prices - Reasons, Impacts and its Policy Implications on Future Sustainable Agricultural Development (The Case of Maize Belt Areas, Western Ethiopia), unpublished paper, June 2001.

9. Tsegaye B. *Incentives for On-farm Conservation in a Center of Diversity: A Case Study of durum wheat (Triticum turgidum L.) Landraces from East Shewa, Central Ethiopia*, Norwegian University of Life Sciences, Philosophiae Doctor Thesis, 2005.
10. Asfaw A Chronic food insecurity rather than availability is becoming the main issue in Ethiopia. Draft report prepared for USAID in Addis Ababa, 2002.
11. Federal Democratic Republic of Ethiopia. EC/1997 GC. *Environmental Policy of Ethiopia*. Environmental Protection Authority with Ministry of Economic Development and Cooperation (MEDAC), Addis Ababa, 1989.
12. Araya H and Edwards S. The Tigray Experience: a success story in sustainable agriculture. *Environment & Development Series 4*. TWN (Third World Network), Penang, 2006, Available at <http://www.twinside.org.sg/title/end/ed04.htm>
13. Edwards S. Greening Ethiopia. *Science in Society* 23, 4-5, 2004.
14. Edwards S. The Tigray Project. *Science in Society* 23, 6-7, 2004.
15. Edwards S. Organic production for Ethiopia. *Science in Society* 23, 8, 2004.
16. Asmelash A. *Dekuaie tefetro: intayn bkhmeyn* (Making compost: what it is, and how is it made). In Tigrinya. Tigray Bureau of Agriculture and Natural Resources and Institute for Sustainable Development, Addis Ababa, Ethiopia, 2002.
17. The yield data from farmers' fields was collected by development agents and local experts supervised and compiled by Arefayne Asmelash and Hailu Araya Project Officer and Sustainable Community Development Team Leader in ISD.
18. Edwards S, Asmelash A, Araya H and Berhan Gebre Egziabher T (2007). The impact of compost use on crop yields in Tigray, Ethiopia, 2000-2006 inclusive. Paper prepared for the FAO International Conference on Organic Agriculture and Food Security, 3-5 May 2007 in FAO, Italy. Available through the FAO web site www.fao.org
19. Annex in Edwards S. *Natural Fertilizer*. Institute for Sustainable Development, Addis Ababa, 2003.
20. *Proclamation No. 488/2006. Ethiopian Organic Agriculture System Proclamation, dated 8 March 2006, Addis Ababa*, Negarit Gazeta 12th year, No. 21. Federal Negarit Gazeta of the Federal Democratic Republic of Ethiopia, Addis Ababa, 2006.
21. Rieks H and Edwards S eds. Organic Chain Development in Ethiopia: Participatory Networking Workshop, Addis Ababa, Ethiopia, 24-25 May 2007. Agro-Eco, the Netherlands and Institute for Sustainable Development, Addis Ababa, Ethiopia, 2007. Also available through www.agroeco.nl

Chapter 12

1. Wolfe LR. Rural-urban migration and the stabilization of Cuban agriculture. Food First, Institute for Food and Development Policy, 17 December 2007, <http://www.foodfirst.org/node/1123>
2. Holt-Gimenez E, Altieri MA and Rosset P. Ten Reasons Why the Rockefeller and the Bill and Melinda Gates Foundations' Alliance for Another Green Revolution Will Not Solve the Problems of Poverty and Hunger in Sub-Saharan Africa. Food First Policy Brief No. 12, October 2006
3. Wright J. *Falta Petroleo! Perspectives on the emergence of a more ecological farming and food system in post-crisis Cuba* 2005, Wageningen/HDRA
4. Murphy C. Cultivating Havana: Urban Agriculture and Food Security in the Years of Crisis, May 1999, www.Foodfirst.org
5. Ho MW. Exploding the food myths in the GM debate. ISIS News 5, July 2000
6. "Success story" Urban farming thrives in Cuba (part one)", Jason Mark, 11 April 2007, [peopleand planet.net, http://www.peopleandplanet.net/doc.php?id=3003](http://www.peopleandplanet.net/doc.php?id=3003)
7. "Success story, urban farming thrives in Cuba (part two)", Jason Mark, 11 April 2007 [peopleand planet.net, http://www.peopleandplanet.net/doc.php?id=3004](http://www.peopleandplanet.net/doc.php?id=3004)

Chapter 13

1. Lim LC. Organic agriculture fights back. *Science in Society* 2002, 16, 30-32.
2. Pimental D, Hepperly P, Hanson J, Douds D and Seidel R. Environmental, energetic, and economic comparisons of organic and conventional farming systems. *BioScience* 2005, 55, 573-82.
3. BANR/NRC 2003 Board on Agriculture and National Resources, National Research Council, *Frontiers in Agricultural Research: Food, Health, Environment, and Communities*. Washington DC, National Academies Press, 2003.
4. Pimental, D et al. Environmental and economic costs of soil erosion and conservation benefits. *Science* 267, 1117-23.
5. Chapter 17 Statistical Abstract of the United States: 2004-2005, Section 17 Agriculture, US Census Bureau, <http://www.census.gov/prod/2004pubs/04/agricult.pdf>

Chapter 14

1. Bt cotton vs. non pesticidal management of cotton: Findings of a study by the Centre for Sustainable Agriculture. 2004-05. www.grain.org/research_files/bt_vs_npm.pdf
2. Jayaraman KS. Indian Bt gene monoculture, potential time bomb. *Nature Biotechnology*, 31 Jan 2005. <http://www.grain.org/research/btcotton.cfm?id=276>
3. Gala R. GM cotton fiascos around the world. *Science in Society* 25, 2005.
4. Men X, Ge F, Edwards CA, Yardim, EN. Influence of pesticide applications on pest and predatory arthropods associated with cotton and non-transgenic cotton plants. *Phytoparasitica*. Oct 2004. 32, 3. 246-254.
5. Xue D. The environmental implications of Bt cotton in China. Greenpeace International. 2002. <http://www.eldis.org/static/DOC14637.htm>
6. Sahai S. New revelations about bad performance of Bt cotton in India. Press Release. 17 Mar 2005. <http://gmwatch.org/archive2.asp?arcid=4994>
7. Sharma D. No Bt cotton, No pests! How cotton farmers are being fleeced. Mar 2005. <http://gmwatch.org/archive2.asp?arcid=4935GMW>
8. Deepa A. Organic farming takes hold in Rajasthan. 1 Apr 2005. www.gmwatch.org/archive2.asp?arcid=5055
9. Sharma D. No pesticides, higher crop yields. The Hindu. 14 Jun 2005 <http://www.thehindu.com/2005/06/14/stories/2005061407011100.htm>

10. Gala R. India's Bt Cotton Fraud. *Science in Society* 26, 27-28, 2005.
11. Government study shows flaws in GM cotton <http://gmwatch.org/archive2.asp?arcid=5542>

Chapter 15

1. Dimitri, C, Greene, C. Recent growth patterns in the US organic food market. USDA-ERS Agriculture Information Bulletin No. AIB777, 2002. US Department of Agriculture Economic Research Service, Washington D.C. www.ers.usda.gov/publication/aib777/aib777.pdf
2. Delate K, and Cambardella, CA. Organic Production. Agroecosystem performance during transition to certified organic grain production. *Agronomy Journal* 2004, 96:1288-1298.

Chapter 16

1. Assessment of the System of Rice Intensification (SRI), Proceedings of an International conference held in Sanya, China, April 1-4, 2002, Cornell International Institute for Food, Agriculture and Development <http://ciifad.cornell.edu/sri/>
2. Uphoff N. Facts and fallacies regarding "Fantastic yields in the system of rice intensification". *Field Crop Research* (in press).
3. Dixit K. Less is more: working miracles in Nepal's rice fields. 15 September 2005 SciDev.Net: <http://www.scidev.net/content/features/eng/less-is-more-working-miracles-in-nepals-rice-fields.cfm>
4. IRRI Profile. <http://www.gmwatch.org/profile1.asp?PrId=296&page=1>
5. "Study: growing more rice with less water", WWF Newsroom, 3 October 2007, http://www.panda.org/news_facts/newsroom/index.cfm?uNewsID=114481

Chapter 18

1. Pretty J. The real costs of modern farming. Resurgence issue 205, 2001, <http://www.resurgence.org/resurgence/issues/pretty205.htm>
2. Beyer P. Should we worry about nitrate in our water? 1999, <http://www.leopold.iastate.edu/pubs/nwl/1999/1999-3-leoletter/99-3nitrate.htm>
3. Mäder P, Fliebbach A, Dubois D, Gunst L, Fried P and Niggli U. 'Soil fertility and biodiversity in organic farming', *Science* 2002, 296, 1694-97.
4. Oehl F, Oberson A, Tagmann HU, Besson JM, Dubois D, Mäder P, Roth H-R and Frossard E. 'Phosphorus budget and phosphorus availability in soils under organic and conventional farming', *Nutrient Cycling in Agroecosystems* 2002, 62, 25-35.
5. Rodale Institute. 1999. '100-year drought is no match for organic soybeans', http://www.rodaleinstitute.org/global/arch_home.html
6. Poudel DD, Horwath WR, Lanini WT, Temple SR and van Bruggen AHC. 'Comparison of soil N availability and leaching potential, crop yields and weeds in organic, low-input and conventional farming systems in northern California', *Agriculture, Ecosystems and Environment* 2002, 90, 125-137.
7. Kramer SB, Reganold JP, Gloer JD, Bohannan BJM and Mooney HA. Reduced nitrate leaching and enhanced denitrifier activity and efficiency in organically fertilized soils. *PNAS* 2006, 103, 4522-7.
8. Pesticide residues are commonly found in our food. Soil Association, <http://www.soilassociation.org/web/sa/saweb.nsf/a71fa2b6e2b6d3e980256a6c004542b4/50e5e6a2558967b280256f3f004ff4c2!OpenDocument&Highlight=2,pesticides>
9. Letourneau DK and Goldstein B. 'Pest damage and arthropod community structure in organic vs. conventional tomato production in California', *J. Applied Ecology* 2001, 38(3), 557-570.
10. "An ordinary miracle", *New Scientist* 2001, Vol. 169, Issue 2276, p. 16.
11. Barzman M and Das L. Ecologising rice-based systems in Bangladesh. *ILEIA Newsletter* 2000, 16(4), 16-17, http://www.agroeco.org/fatalharvest/articles/ecologising_rice.pdf
12. IFOAM. 2002. 'Organic agriculture and biodiversity: Making the links', Germany: IFOAM, IUCN and BfN. See also Stolton S. *Organic Agriculture and Biodiversity*, IFOAM Dossier 2, 2002.
13. Altieri MA, Rosset P and Thrupp LA. 1998. The potential of agroecology to combat hunger in the developing world, http://www.agroeco.org/fatalharvest/articles/potential_of_agroeco_ch19.pdf
14. Azeez G. 2000. *The biodiversity benefits of organic farming*, Bristol: Soil Association.
15. Hole DG, Perkins AJ, Wilson JD, Alexander IH, Grice PV and Evans AD. Does organic farming benefit biodiversity? *Biological Conservation* 2005, 122, 113-30.
16. Burcher S. 'Herbalert to the rescue', *Science in Society* 2003, 18.
17. Pimbert M. 'Sustaining the multiple functions of agricultural biodiversity'. FAO background paper series for the Conference on the Multifunctional Character of Agriculture and Land, The Netherlands, September 1999.
18. Ho MW and Cummins J. Killing bees series. *Science in Society* 2007, 34, 34-38.
19. Cummins J Requiem for the honeybee. *Science in Society* 2007, 34, 37-38.
20. Cummins J. Parasitic fungi and pesticides act synergistically to kill honeybees. *Science in Society* 2007, 35, 35.
21. FAO. Biodiversity and the ecosystem approach in agriculture, forestry and fisheries, Proceedings of a satellite even on the occasion of the Ninth Regular Session of the Commission on Genetic Resources for Food and Agriculture, Rome 12-13 October 2002, FAO, Rome.
22. Scialabba NE-H, Grandi C and Henatsch C. 'Organic agriculture and genetic resources for food and agriculture', in *Biodiversity and the ecosystem approach in agriculture, forestry and fisheries*, p. 72-99, 2002, Rome: FAO.
23. Ho MW and Ulanowicz R. Sustainable systems as organisms? *BioSystems* 2005, 82, 39-51. <http://www.i-sis.org.uk/onlinestore/papers.php>
24. Tilman D, Reich PB, Knops J, Wedin D, Mielke T and Lehman C. 'Diversity and productivity in a long-term grassland experiment', *Science* 2001, 294, 843-5.
25. Ho MW. 'Biodiverse systems two to three times more productive than monocultures', *Science in Society* 2002, 13/14, 36.

26. Zhu Y, Chen H, Fan J, Wang Y, Li Y, Chen J, Fan JX, Yang S, Hu S, Leung H, Mew TW, Teng PS, Wang Z and Mundt C. 'Genetic diversity and disease control in rice', *Nature* 2000, 406, 718-722.
27. "Simple Method Found to Vastly Increase Crop Yields", By Carol Kaesuk Yoon, *New York Times*, 22 August 2000.
28. Altieri MA, Rosset P and Thrupp LA. 1998. The potential of agroecology to combat hunger in the developing world, http://www.agroeco.org/fatalharvest/articles/potential_of_agroeco_ch19.pdf
29. Barzman M and Das L. 'Ecologising rice-based systems in Bangladesh', ILEIA Newsletter 2000, 16(4), 16-17, http://www.agroeco.org/fatalharvest/articles/ecologising_rice.pdf
30. Bennack D, Brown G, Bunning S and de Cunha MH. 'Soil biodiversity management for sustainable and productive agri culture: Lessons from case studies', in *Biodiversity and the ecosystem approach in agriculture, forestry and fisheries*, p.196-223, 2002, FAO.
31. Stolze M, Piorr A, Häring A and Dabbert S. 1999. *Environmental and resource use impacts of organic farming in Europe*, Commission of the European Communities, Agriculture and Fisheries (FAIR) specific RTD programme, Fair3-CT96-1794, "Effects of the CAP-reform and possible further development on organic farming in the EU".
32. FAO. 2002. *Organic agriculture, environment and food security*, Scialabba NE-H and Hattam C (eds), Rome: FAO.

Chapter 19

1. Goldsmith E. Feeding the world under climate change. *Science in Society* 2004, 24, 34-36.
2. Smith P, Martino D, Cai Z, Gwary D, Janzen H, Kumar P, McCarl B, Ogle S, O'Mara F, Rice C, Choles B, Sirotenko O. Agriculture. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA. (eds)), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
3. Barker T, Bashmakov I, Alharthi A, Amann M, Cifuentes L, Drexhage J, Duan M, Edenhofer O, Flannery B, Grubb M, Hoogwijk M, Ibitoye F I, Jepma CJ, Pizer WA, Yamaji K. Mitigation from a cross-sectoral perspective. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Metz B, Davidson OR, Bosch PR, Dave R, Meyer LA. eds), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.
4. Scialabba NE-H and Hattam C (eds) *Organic agriculture, environment and food security*, FAO, Rome, 2002.
5. Petersen C, Drinkwater LE and Wagoner P. *The Rodale Institute Farming Systems Trial: The First 15 Years*, The Rodale Institute, 1999.
6. Lötjönen T. Machine work and energy consumption in organic farming. *Ecology and Farming* 2003, 32, 7-8, IFOAM.
7. Reganold JP, Glover JD, Andrews PK and Hinman JR. 'Sustainability of three apple production systems', *Nature* 2001, 410, 926-930.
8. "Organic apples win productivity and taste trials", 10 August 2001, Pesticide Action Network Updates Service, <http://www.panna.org>
9. Dalgaard T. 'On-farm fossil energy use', *Ecology and Farming* 2003, 32, 9, IFOAM.
10. Norton B. UK direct and indirect energy use, UK energy use Statistics, 2004, BERR, Department for Business Enterprise & Regulatory Reform, <http://www.berr.gov.uk/energy/statistics/publications/ecuk/overall/page17954.html>
11. Greenhouse gas emissions, down since 1990, National Statistics Online, <http://www.statistics.gov.uk/cci/nugget.asp?id=901>
12. Biermann S, Rathke GW, Hülsbergen KJ and Diepenbrock W. Energy Recovery by Crops in Dependence on the Input of Mineral Fertilizer, Final Report, 1999, European Fertilizer Manufacturers Association, <http://www.efma.org/publications/Energy%20Study/endbericht.pdf>
13. Energy use and organic farming. Soil Association Briefing paper, October 2007
14. Pimentel D. Impacts of organic farming on the efficiency of energy use in agriculture. An Organic Center State of Science Review, Organic Center, August 2006, http://organic.insightd.net/reportfiles/ENERGY_SSR.pdf
15. Ho MW. Biofuels for oil addicts. Cure worse than the addiction? *Science in Society* 2006, 30, 29-30.
16. Summary for Policymakers of the Synthesis Report of the IPCC Fourth Assessment Report, Draft copy 16 November 2007, Subject to final copyedit, http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr_spm.pdf
17. Executive Summary Inventory of U.S. Greenhouse Gas Emissions and sinks: 1990-2005. April 2007 <http://www.epa.gov/climatechange/emissions/downloads06/07ES.pdf>
18. Garrett T. Sources for the chart showing total UK food consumption GHG emissions as percentage of total UK consumption related GHGs. Work in progress, 13 March 2007, Food Climate Research Network, <http://www.fcrn.org.uk/>
19. Observatory monitoring framework indicator data sheet, Environmental impact: Climate change Indicator DD1: Methane emissions, 2007, http://statistics.defra.gov.uk/esg/ace/dd1_data.htm
20. Observatory monitoring framework indicator data sheet, Environmental impact: Climate change Indicator DD2: Nitrous oxide emissions, http://statistics.defra.gov.uk/esg/ace/dd2_data.htm
21. AEA Greenhouse Gas Inventories for England, Scotland, Wales and Northern Ireland: 1990 - 2005, Report to Department for Environment, food and Rural Affairs, The Scottish Executive, The Welsh assembly Government and The Northern Ireland Department of Environment EPEO/ED05452200, AEAT/ENR/R/2500 Draft Final, August 2007
22. Stolze M, Piorr A, Häring A and Dabbert S. 1999. *Environmental and resource use impacts of organic farming in Europe*, Commission of the European Communities, Agriculture and Fisheries (FAIR) specific RTD programme, Fair3-CT96-1794, "Effects of the CAP-reform and possible further development on organic farming in the EU".
23. "Cutting methane emissions of flatulent cows", Organic Inform, Elm Farm, 13 July 2007, <http://www.organicinform.org/newsitem.aspx?id=217>
24. Stern Review on the Economics of Climate Change, HM Treasury, 2007, http://www.hm-treasury.gov.uk/independent_reviews/stern_review_economics_climate_change/stern_review_report.cfm
25. Saunders PT. The economics of climate change. *Science in Society* 2007, 33, 20-23.
26. Clark MS, et al. 1999. 'Crop-yield and economic comparisons of organic, low-input, and conventional farming systems in California's Sacramento Valley', *American Journal of Alternative Agriculture* 14 (3), 109-121; and Clark MS et al. 1998. 'Changes in soil chemical properties resulting from organic and low-input farming practices', *Agronomy Journal* 90, 662-671.

27. Drinkwater LE *et al.* 'Fundamental differences between conventional and organic tomato agroecosystems in California', *Ecological Applications* 1995, 5(4), 1098-1112.
28. Petersen C, Drinkwater LE and Wagoner P. *The Rodale Institute Farming Systems Trial: The First 15 Years*, The Rodale Institute, 1999.
29. Rothamsted Research, Guide to the Classical and other Long-term Experiments, Datasets and Sample Archive, Rothamsted Research, Harpenden, 2006. www.rothamsted.ac.uk
30. Hepperly P. Organic farming sequesters atmospheric carbon and nutrients in soils. The Rodale Institute, Pennsylvania, USA, 15 October 2003, http://www.newfarm.org/depts/NFfield_trials/1003/carbonwhitepaper.shtml
31. "New finding: organic farming combats global warming...big time" Laura Sayre, The New Farm, 10 October 2003, http://www.newfarm.org/depts/NFfield_trials/1003/carbonsequest_print.shtml
32. Global land use area change matrix, FAO Corporate Document Repository, 1 January 2008, <http://www.fao.org/docrep/010/ag049e/AG049E03.htm>
33. Garrett T. Overall UK consumption related GHGs, April 2007, Food Climate Change Research Network, <http://www.fcfn.org.uk/frcnresearch/publications/Overall%20food%20GHGs.doc>
34. How much greenhouse gases in our plate? Jean-Marc Jancovici. March 2004 http://www.manicore.com/anglais/documentation_a/greenhouse/plate.html
35. Andersson K, Ohlsson T Olsson P. Screening life cycle assessment (LCA) of tomato ketchup: a case study. *Journal of Cleaner Production* 1998, 6, 277-88.

Chapter 20

1. "Official: organic really is better", Jon Ungoed-Thomas, *The Sunday Times* 28 October 2007, <http://www.timesonline.co.uk/tol/news/uk/health/article2753446.ece>
2. Wrench GT. *The Wheel of Health*, C.W. Daniel Company Ltd., London; 1938, reprinted 1960 by Lee Foundation for Nutritional Research, Milwaukee, Wisconsin, U.S.A.; reprinted 1990 by Bernard Jensen International, Escondido, California.
3. Wrench GT (ref. 1), pp.126-7.
4. Wrench GT (ref.1), pp. 125-7.
5. "New studies back benefits of organic diet" Stephen Leahy, Final Call.com News, 20 March 2006, http://www.finalcall.com/artman/publish/article_2497.shtml
6. The Food Commission meat and dairy: where have the minerals gone? *Food Magazine* 2006, 72, 10.
7. Worthington V. Nutritional quality of organic versus conventional fruits, vegetables, and grains. *Journal of Alternative and Complementary Medicine* 2001, 7, 161-73.
8. Brandt K and Molgaard J. Organic agriculture: does it enhance or reduce the nutritional value of plant foods *J.Sci.FoodAgric.* 2001, 81, 924-31.
9. Magkos F, Arvaniti F and Zampelas A Organic food: nutritious food or food for thought? A review of the evidence. *International Journal of Food Sciences and Nutrition* 2003, 54, 357-71.
10. Gala R. Health promoting germs. *Science in Society* 2005, 26, 29, <http://www.i-sis.org.uk/isisnews.php>
11. Heaton S. *Organic farming, food quality and human health: A review of the evidence*. Soil Association, Bristol, 2001.
12. Heaton S. (ref. 9), back cover.
13. Daldy Y. Food production without artificial fertilisers. *Nature*, 1940, 145(3684), 905-6.
14. Plaskett LG. Clinical application of a nutritional cancer therapy with prescribed diet and nutrients. The Nutritional Cancer Therapy Trust, Surrey, UK, 2000.
15. Ashton, C, Director of the Nutritional Cancer Therapy Trust, personal communication in April 2001 to S Heaton (ref. 10).
16. USDA Agricultural Research Services Report No. 2, 'Evaluation of Research in US on Human Nutrition', 1971, cited in Heaton S. *Organic Farming, Food Quality and Human Health*, p.11, Soil Association, Bristol, 2001.
17. McCance RA and Widowson EM, 1940 to 1991, commissioned first by the Medical Research Council and later by the Ministry of Agriculture, Fisheries and Food, and the Royal Society of Chemistry.
18. *What Doctors Don't Tell You*, Dec. 2002, vol. 13, No. 9, p. 4
19. Mozafar A. Nitrogen fertilisers and the amount of vitamins in plants: a review. *J Plant Nutrition*, 1993, 16(12), 2479-506.
20. Mozafar A. Enrichment of some B-vitamins in plants with application of organic fertilisers. *Plant and Soil*, 1994, 167, pp. 305-11.
21. Brandt K and Mølgaard JP. Organic agriculture: does it enhance or reduce the nutritional value of plant foods? *J Sci of Food and Agric*, 2001, 81, pp. 924-931.
22. Worthington V. 'Nutritional quality of organic versus conventional fruits, vegetables, and grains', *The Journal of Alternative and Complementary Medicine* 2001, 7(2), 161-173.
23. "Organic milk 'higher in vitamins'" BBC News, 7 January 2005, <http://news.bbc.co.uk/1/hi/health/4153951.stm>
24. Kris-Etherton PM, Hecker KD, Bonanome A, Coval SM, Binkoski AE, Hilpert KF, Griel AE and Etherton TD. Bioactive compounds in foods: their role in the prevention of cardiovascular disease and cancer *Am J Med.* 2002 Dec 30; 113 Suppl 9B:71S-88S
25. Yao, LH, Jiang YM, Shi J, Tomas-Barberan FA, Datta N, Singanusong R, Chen SS. Flavonoids in food and their health benefits *Plant Foods Hum Nutr* 2004, 59, 113-22.
26. Ames BN. Dietary carcinogens and anticarcinogens: oxygen radicals and degenerative diseases. *Science* 1983, 221, 1256-64.
27. Carbonaro M, Mattera M, Nicoli S, Bergamo P and Cappeloni M. Modulation of antioxidant compounds in organic vs conventional fruit (Peach, *Prunus persica* L. and Pear, *Pyrus communis* L.) *J Agricultural and Food Chemistry* 2002, 50, 5458-62
28. Asami D, Hong Y, Barrett D and Mitchell A. Comparison of total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry and corn grown using conventional, organic and sustainable agricultural practices" *J. Agricultural and Food Chemistry* 2003, 51, 1237-41.
29. Organic food 'better' for heart", BBC News, 5 July 2007, <http://news.bbc.co.uk/1/hi/health/6272634.stm>

30. Colic M and Pavelic K. Molecular mechanisms of anticancer activity of natural dietetic products. *J. Mol. Med.* 2000, 78,333-6.
31. McCarty M. Current prospects for controlling cancer growth with non-cytotoxic agents-nutrients, phytochemicals, herbal extracts, and available drugs. *Medical Hypothesis* 2001, 56,137-54
32. Youdim K and Joseph J A possible emerging role of phytochemicals in improving age-related neurological dysfunctions: A multiplicity of effects. *Free Radical Biology and Medicine* 2001, 6,583-94
33. Olsson ME, Andersson CS, Oredsson S, Berglund RH and Gustavsson KE. Antioxidant levels and inhibition of cancer cell proliferation in vitro by extracts from organically and conventionally cultivated strawberries. *J Agric Food Chem.* 2006, 54, 1248-55.
34. Lundegardh B and Mortensson A. Organically produced plant foods-evidence of health benefits *ActaAgric.Scand.SectB , Soil and Plant Sci.* 2003,53,3-15.
35. Wang S and Lin H. Compost as a soil supplement increases the level of antioxidant compounds and oxygen radical absorbance capacity in strawberries. *J Agric Food Chem.* 2003, 51, 6844-50.
36. Wang SY, Feng R, Lu Y, Bowman L and Ding M. Inhibitory effect on activator protein-1, nuclear factor-kappaB, and cell transformation by extracts of strawberries (*Fragaria x ananassa* Duch.). *J Agric Food Chem.* 2005, 53, 4187-93.
37. Lombardi-Boccia G, Lucarini M, Lanzi S, Aguzzi A and Cappelloni M. Nutrients and antioxidant molecules in yellow plums (*Prunus domestica* L.) from conventional and organic productions: a comparative study. *J Agric Food Chem.* 2004, 52, 90-4.
38. Ramos S, Alia M, Bravo L and Goya L. Comparative effects of food-derived polyphenols on the viability and apoptosis of a human hepatoma cell line (HepG2). *J Agric Food Chem.* 2005, 53(4), 1271-80.
39. "Cancer concern over vegetable nitrates", BBC News, 15 February 2002,<http://news.bbc.co.uk/1/hi/scotland/1824156.stm>
40. Organic standards: work in process, Soil Association, 11 November 2005, <http://www.soilassociation.org/web/sa/saweb.nsf/b0062cf005bc02c180256a6b003d987f/f766091f2395f34780256e52005f1084!OpenDocument&Highlight=2,additives>
41. Pasley MA. Do you know what you are eating? Integrative Nutrition Specialist, synergy@integrative-nutrition-specialist.com
42. Saunders PT. Food colouring confirmed bad for children, Food Standards Agency refuses to act. *Science in Society* 2007, 37
43. Feingold, BF. Hyperkinesis and Learning Disabilities Linked to Artificial Food Flavors and Colors. *American Journal of Nursing* 1975, 75, 797-803.
44. McCann D, Barrett A, Cooper A, Crumpler D, Dalen L, Grimshaw K, Kitchin E, Lok K, Porteous L, Prince E, Sonuga-Barke E, Warner JO, Stevenson J. Food additives and hyperactive behaviour in 3-year-old and 8/9-year-old children in the community: a randomised, double-blinded, placebo-controlled trial. *The Lancet* (published online: September 6, 2007, DOI:10.1016/S0140-6736(07)61306-3).
45. "Pesticides in your food - new guide reveals the real problem", Soil Association Press Release 29 October 2004, <http://www.soilassociation.org/web/sa/saweb.nsf/b0062cf005bc02c180256a6b003d987f/3038050d31bc42f180256f3b0044eaaa!OpenDocument&Highlight=2,Pesticides>
46. "Pesticides in school fruit - cause for concern?" Soil Association, <http://www.soilassociation.org/web/sa/saweb.nsf/ed0930aa86103d8380256aa70054918d/8f20bc2bb8d9f5698025708a0399f8b!OpenDocument>
47. Litovitz TL, Smilkstein M, Felberg L, et al 1996 Annual Report of the American Association of Poison Control Centers Toxic Exposure Surveillance System. *Am J Emerg Med* 1997, 15, 447-500.
48. Trouble on the farm, Growing up with pesticides in agricultural communities. Natural Resources Defence Council, (accessed 11 Nov 2007), <http://www.nrdc.org/health/kids/farm/chap1.asp>
49. *Pesticides in the Diets of Infants and Children*, National Research Council, National Academy Press, Washington DC, 1993.
50. Pesticides and food: Health problems pesticides may pose, US Environmental Protection Agency, 2 May 2006, <http://www.epa.gov/pesticides/food/risks.htm>
51. Pesticides and food: Why children may be especially sensitive to pesticides, 2 May 2006, <http://www.epa.gov/pesticides/food/pest.htm>
52. Lu C, Toepel K, Irish R, Fenske RA, Barr DB and Bravo R. Organic diets significantly lower children's dietary exposure to organophosphorus pesticides. *Environ Health Perspect.* 2006,114(2):260-3.
53. Juhler RK, Larsen SB, Meyer O, Jensen ND, Spano M, Giwercman A and Bonde JP. Human semen quality in relation to dietary pesticide exposure and organic diet. *Arch Environ Contam Toxicol.* 1999, 37(3), 415-23.
54. Lindheim SR, Barad DH, Zinger M, Witt B, Amin H, Cohen B, Fisch H and Barg P. Abnormal sperm morphology is highly predictive of pregnancy outcome during controlled ovarian hyperstimulation and intrauterine insemination. *J Assist Reprod Genet.* 1996, 13(7), 569-72.
55. Sakkas D, Seli E, Manicardi GC, Nijs M, Ombelet W and Bizzaro,D. The presence of abnormal spermatozoa in the ejaculate: did apoptosis fail? *Hum Fertil (Camb).* 2004, 7(2), 99-103.
56. "Hormones: here's the beef", Janet Raloff, Science News Online, 5 Jan 2002, <http://www.sciencenews.org/articles/20020105/bob13.asp>
57. Epstein SS. Unlabeled milk from cows treated with biosynthetic growth hormones: A case of regulatory abdication. *International Journal of Health Services* 1996, 26(1), 173-85.
58. Antibiotics use in farming and human health, Soil Association Briefing Paper 26 February 2007, <http://www.soilassociation.org/web/sa/saweb.nsf/b0062cf005bc02c180256a6b003d987f/80256ad800554549802567e0004dc698!OpenDocument&Highlight=2,antibiotics>
59. Cummins J. Increased mycotoxins in organic produce? *Science in Society* 2005, 25, 20-21.
60. "Are organic standards under attack from GMOs? " Natural Choices, 13 June 2007, http://www.naturalchoices.co.uk/Organic-standards-under-attack?id_mot=7
61. Ho MW. *Living with the Fluid Genome*, TWN and ISIS, Penang and London, 2003.
62. Ho MW. Mass death in sheep grazing on Bt cotton. *Science in Society* 2006, 30, 12-13.

63. Ho MW. More illnesses linked to Bt crops. *Science in Society* 2006, 30, 8-9.
64. Ho MW. Transgenic pea that make mice ill. *Science in Society* 2006, 29, 28-29.
65. Ho MW. GM soya fed rats: stunted, dead, or sterile. *Science in Society* 2007, 33, 4-6.
66. Ho MW, et al. *GM Science Exposed, Hazards Ignored, Fraud, Regulatory Sham, Violation of Farmers' Rights*, ISIS CD Book, A dossier of damning evidence against GMOs, 2007.

Chapter 21

1. Ho MW. 2007 GM food nightmare unfolding and the regulatory sham. *Science in Society* 33, 32-35, 2007 GM Science Exposed, ISIS CD Book
2. Gala R. 2005 GM cotton fiascos around the world. *Science in Society* 25, 26-27
3. EJF 2007 *The Deadly Cost of Chemicals in Cotton*. The Environmental Justice Foundation in collaboration with the Pesticide Action Network. ISBN 1-904523-10-2
4. World Health Organization 2004 Recommended Classification of Pesticides by Hazard
<http://www.inchem.org/documents/pds/pdsotther/class.pdf>
5. Pesticide Action Network, *Moral Fibre: Organic Cotton* A documentary film
6. Toulmin C. From harvest to high street. Rachel Carson Memorial Lecture *Pesticides News* 2006 74:12-16.
7. Ho. M.W. 2005 Zambia holding firm to GM ban amid aggressive awareness campaign. *Science in Society* 28, 25,
8. Uzbekistan: National Environmental Action Plan. International Bank for Reconstruction and Development. /World Bank 1999
9. EJF 2005 White Gold: the true cost of cotton. 1-904523-08-0
10. Uzbekistan: Environmental disaster on a colossal scale An MSF Article November 1, 2000
http://www.msf.org/msfinternational/invoke.cfm?component=article&objectid=6589D208-DC2C-11D4-B2010060084A6370&method=full_html
11. Sanfilippo D. *Wear Organic News* November 2007
12. Organic Exchange. Global organic cotton apparel and home products market tops one billion dollars in 2006, says new Organic Exchange report. October 31, 2007

Chapter 22

1. Reganold JP, Glover JD, Andrews PK and Hinman JR . 'Sustainability of three apple production systems', *Nature* 2001, 410, 926-930.
2. 'Organic apples win productivity and taste trials', 10 August 2001, Pesticide Action Network Updates Service,
<http://www.panna.org>
3. Pacini C, Wossink A, Giesen G, Vazzana C and Huirne R. 'Evaluation of sustainability of organic, integrated and conventional farming systems: a farm and field-scale analysis' *Agriculture, Ecosystems and Environment* 2003, 95, 273-288.
4. Rosset PM. 1999. 'The multiple functions and benefits of small farm agriculture in the context of global trade negotiations', Policy Brief No. 4, Institute for Food and Development Policy,
<http://www.foodfirst.org/pubs/policybs/pb4.html>
5. Altieri MA, Rosset P and Thrupp LA. 1998. *The potential of agroecology to combat hunger in the developing world*,
http://www.agroeco.org/fatalharvest/articles/potential_of_agroeco_ch19.pdf
6. Porter PM, Huggins DR, Perillo CA, Quiring SR and Crookston RK. 'Organic and other management strategies with two- and four-year crop rotations in Minnesota', *Agronomy Journal* 2003, 95(2), 233-244
7. Welsh R. The Economics of Organic Grain and Soybean Production in the Midwestern United States. Henry A. Wallace Institute for Alternative Agriculture. 1999. http://www.agroeco.org/fatalharvest/articles/economics_organic_prod.pdf
8. Petersen C, Drinkwater LE and Wagoner P. 1999. *The Rodale Institute Farming Systems Trial: The First 15 Years*, The Rodale Institute.
9. Pretty J and Hine R. 2001. Reducing food poverty with sustainable agriculture: a summary of new evidence, Centre for Environment and Society, Essex University,
www2.essex.ac.uk/ces/ResearchProgrammes/CESOccasionalPapers/SAFErepSUBHEADS.htm
10. Rosset P. 'Taking seriously the claim that genetic engineering could end hunger: A critical analysis', pp 81-93 in Britt Bailey and Marc Lappé (eds), *Engineering the Farm: Ethical and Social Aspects of Agricultural Biotechnology*. Washington, DC: Island Press. 2002.
11. Chambers R, Pacey A and Thrupp LA. 1989. *Farmer First: Farmer Innovation and Agriculture Research*, London: Intermediate Technology Publications.
12. Charvet JP. *Transrural Initiatives*, 25 January, Paris, 2005.
13. Pimbert M. Supporting locally determined food systems: the role of local organizations in farming, environment and people's access to food. In *How to Make Poverty History*, The central role of local organizations in meeting the MDGs (Bigg T and Satterthwaite D eds), pp. 129- 155, iied, International Institute for Environment and Development, London, 2005.
14. Scoones I and Thompson J. 1994. *Beyond Farmer First: Rural People's Knowledge*, *Agricultural Research and Extension Practice*, London: Intermediate Technology Publications.
15. *Agroecological Innovations: Increasing Food Production with Participatory Development*. Edited by Norman Uphoff. Earthscan Publications. 2002.
16. Scialabba NE-H and Hattam C. *Organic agriculture, environment and food security*, (eds), FAO, Rome 2002.
17. Lim LC. Ethiopia's own agriculture, *Science in Society* 2003, 17, 7-8.
18. Uphoff N and Altieri MA. 1999. *Alternatives to conventional modern agriculture for meeting world food needs in the next century* (Report of a Conference "Sustainable Agriculture: Evaluation of New Paradigms and Old Practices", Bellagio, Italy). Ithaca, NY: Cornell International Institute for Food, Agriculture, and Development.
19. Pretty J. *Regenerating agriculture*. Earthscan, London, 1995.
20. Rundgren G. *Organic Agriculture and Food Security*, IFOAM Dossier 1, 2002.

- Boyd T. *Cusgarne Organics local money flows*, London: New Economics Foundation and The Countryside Agency, 2001.

Chapter 23

- Zeigler J. *The Extent of Chronic Hunger and Malnutrition in India* presented to the United Nations Human Rights Council in Geneva on September 22, 2006
- Bhaskar Save. Open letter: Mounting suicides and National Policy for farmers, 2 August 2006, translated by Bharat Mansata <http://www.gmwatch.org/archive2.asp?arcid=6839>
- Shiva V. Masculinization of the motherland, in *Ecofeminism*, 8:108-109 © Zed Books 1993 ISBN 1856491560
- "Hope has withered for India's farmer", Henry Chu, *The Los Angeles Times*, 11 August 2006.
- Sharma D. Farmer Suicides. *Third World Resurgence*, 2006 no 191, 2-3.
- Biru B.K., Barpujari, I. Jan Sunwai (People's Jury) on the present agrarian crisis. Gene Campaign, 2007. <http://www.genecampaign.org/home/Reports/THE%20AGRARIAN%20CRISIS%20IN%20INDIA.pdf>
- Gala R. Indian cotton farmers betrayed. *Science in Society* 29, 34-37, 2006
- Shiva V. Reducing Scientists to bio-coolies for industry. *Science in Society* 28, 32-33, 2005.
- Court stays fresh field trials of GM crops. *The Hindu*, 23 September 2006. <http://www.hindu.com/2006/09/23/stories/2006092316540400.htm>
- Rs 160 bn package for farmers in 4 suicide-prone states http://www.infochangeindia.org/Agriculture/top.jsp?section_idv=10#4686
- Ho MW. More illnesses linked to Bt crops. *Science in Society* 30, 8-10, 2006.
- Ho MW. Mass deaths in sheep grazing on Bt cotton. *Science in Society* 30, 12-13, 2006.
- Gala R. Return to organic cotton and avoid the Bt cotton trap. *Science in Society* 29, 38-39, 2006.
- Mansata B. *The Vision of Natural Farming*. © Earthcare Books, 2006 Mumbai (in press)

Chapter 25

- Herrmann SM, Anyamba A, Tucker CJ. Recent trends in vegetation dynamics in the African Sahel and their relationship to climate. *Global Environmental Change* 2005, 14, 394-404
- Reij C, Tappan G, Belemvire A. Changing land management practices and vegetation on the Central Plateau of Burkina Faso (1968-2002). *J Arid Environments* 2005, 63, 532-59.
- Reji C and Steeds D. Success stories in Africa's drylands: supporting advocates and answering skeptics. A paper commissioned by the Global Mechanism of the Convention to Combat Desertification, Centre for International Cooperation, Vrije Universiteit, Amsterdam.
- "More plants make more rain" Richard van Noorden, *Naturenews*, Published online 25 September 2006; [doi:10.1038/news060925-1](http://www.nature.com/news/060925-1)
- Los SO, Weedon GP, North PRJ, Kaduk JD, Taylor CM and Cox PM. An observation-based estimate of the strength of rainfall-vegetation interactions in the Sahel. *Geophysical Research Letters* 2006, 33, L16402, [doi:10.1029/2006GL027065](http://www.jgrl1.gatech.edu/cgi-bin/jgrl/jgrl2006/2006GL027065), 2006
- Pearce F. Desert harvest. *New Scientist* 2001, 27 October, 44-47.
- Mazzucato V. and Niemeijer D. Overestimating land degradation, underestimating farmers in the Sahel, *Drylands Programme Issue Paper No. 101*, London: International Institute for Environment and Development, 2001, http://www.iied.org/pdf/dry_ip101eng.pdf
- "Trees and crops reclaim desert in Niger", Lydia Polgreen, International Herald Tribune 11 February 2007, <http://www.ihl.com/articles/2007/02/11/news/niger.php?page=1>
- "More crops for Africa as trees reclaim the desert", Andy Coghlan, *New Scientist*, 14 October 2006, 192, 11.

Chapter 27

- Stoop WA, Uphoff N and Kassam A. A review of agricultural research issues raised by the system of rice intensification (SRI) from Madagascar: opportunities for improving farming systems for resource-poor farmers. *Agric Sys* 2002, 71, 249-74.
- Sheehy JE, Peng S, Dobermann A, Mitchell C, Ferrer A, Yang J, Zou Y, Zhong X and Huang J. Fantastic yields in the system of rice intensification: fact or fallacy? *Field Crops Res* 2004, 88, 1-8.
- "Feast or famine?" Christopher Surrige, *Nature news feature*, 2004, 428, 360-1.
- Uphoff N. Facts and fallacies regarding "Fantastic yields in the system of rice intensification". Unpublished preprint, courtesy of the author.
- Yang L-P. Keynote address Proceedings of international conference, *Assessment of the System of Rice Intensification (SRI)*, Sanya, China, April 1-4, 2002.
- Satyanarayana A. Rice, research and real life in the field. *Nature correspondence* 2004, 429, 803.
- Satyanarayana A. Top Indian rice geneticist rebuts SRI critics. *Science in Society* 2004, 23, 13.
- Stoop WA and Kassam AH. The SRI controversy: a response. *Field Crops Research* 2005, 91, 357-60.

Chapter 28

- Burstyn B., Burstyn T. How to Save the World. Cloud South Films <http://howtosavetheworld.co.nz/>
- Proctor P. Grasp the Nettle: Making Biodynamic Farming and Gardening Work. Godwit Publishing ISBN 9781869416577 New edition January 2008.
- Biodynamic farming and compost preparation. ATTRA. The Appropriate Technology Transfer for Rural Agriculture. (USDA Rural Business-Co-operative Service *Alternative Farming Systems Guide* www.attra.ncat.org)
- Steiner R. Spiritual Foundations for the Renewal of Agriculture, Held at Koberwitz, Silesia, June 7 to June 16, 1924

5. Ho MW, Bunyard P, Saunders PT, Bravo E and Gala R. *Which Energy?* 2006 ISIS Energy Report, Institute of Science in Society, London, 2006. <http://www.i-sis.org.uk/onlinestore/books.php#238>
6. Earth Democracy <http://www.navdanya.org/earthdcracy/index.htm>
7. Carpenter-Boggs L, Kennedy AC. and Reganold JP. Organic and biodynamic management. Effects of soil biology. *Soil Science Society of America Journal* 2000 64, 1651-1659. <http://soil.sciijournals.org/cgi/content/full/64/5/1651>
8. Carpenter-Boggs L, Reganold JP and Kennedy AC. Effects of biodynamic preparations on compost. *Biological Agriculture and Horticulture* 2000, 17: 313-328. <http://www.ars.usda.gov/SP2UserFiles/Place/36450000/Products-Reprints/2000/865.pdf>
9. Reganold JP, Palmer AS, Lockhart JC, and Macgregor AN. Soil quality and financial performance of biodynamic and conventional farms in New Zealand. *Science* 1993, 260 (5106), 344-349. <http://www.sarep.ucdavis.edu/NEWSLTR/v6n2/sa-13.htm>
10. Brinton W. Sustainability of Modern Composting: Intensification versus Costs and Quality. Proceedings of Compost Seminar, PASA, Penn State University, in *Biodynamics* Summer 97 Woods End Agricultural Research Institute
11. Biodynamics under threat <http://www.biodynamic.org.uk/Biodynamic%20Preparations.htm>
12. Cost benefit analysis of Foot and Mouth disease controls 2005, <http://www.defra.gov.uk/animalh/diseases/fmd/pdf/costben.pdf>
13. EJJF 2007. The deadly cost of chemicals in cotton. The Environmental Justice Foundation with the Pesticides Action Network. (PAN) ISBN 1-904523-10-2.
14. Biru B, Barpuhjar I. Gene Campaign. Jan Sunwai (citizen's jury) on the present agrarian crisis. A report <http://www.genecampaign.org/home/Reports/THE%20AGRARIAN%20CRISIS%20IN%20INDIA.pdf>
15. biORE http://www.remei.ch/fileadmin/upload/en/pdf/biore-project/india/Information_about_bioRe_India.pdf

Chapter 30

1. FAO *Global Forest Resources Assessment 2000* and UNEP *Global Biodiversity Outlook 2001*.
2. Altieri M. Agroecology versus ecoagriculture. *Science in Society* 2005, 25, 17-20.
3. Ho MW. Living energy series. *Science in Society* 2004, 21, 46-51.
4. Ho MW. Energy, productivity & biodiversity. *Science in Society* 2004, 21, 48-50.
5. Ho MW. Why are organisms so complex? A lesson in sustainability. *Science in Society* 2004, 21, 50-51.
6. Lähde E. Silvicultural alternatives in Boreal forests. Preprint, courtesy of authors.
7. Lähde E, Laiho O, Norokorpi Y. 1999a. Diversity-oriented silviculture in the Boreal Zone of Europe. *For. Ecol. Manage* 1999a, 118, 223-243.
8. Lähde E, Laiho O, Norokorpi Y and Saksa T. 1991. The structure of advanced virgin forests in Finland. *Scand. J. For. Res.* 1991, 6, 527-537
9. Lähde E, Laiho O, Norokorpi Y and Saksa T. 1999b. Stand structure as the basis of diversity index. *For. Ecol. Manage.* 1999b, 115, 213-220.
10. Lähde E, Laiho O, Norokorpi Y and Saksa T. Structure and yield of Norway Spruce-dominated stands after single-tree selection and low thinning. Poster
11. Coates, K.D. & Steventon, J.D. 1995. Patch retention harvesting as a technique for maintaining stand level biodiversity in forests of North Central British Columbia. In: Bamsey, S. R. (ed.). *Innovative silviculture systems in boreal forests*. Proceedings IUFRO Symposium in Edmonton, Alberta, Canada. Oct. 2-8. 1994. Natural Resources Canada. Canadian Forest Service. pp. 102-106.
12. Balmford, A., *et al.* Economic reasons for conserving wild nature. *Science* 297, 950-953, 2002.

Chapter 31

1. Pathirana KK, Mangalika ULP, Liyanage, M. De S., Ørskov, E.R. (1996) Effect of grazing and supplementation in a coconut plantation on cattle production, coconut yield and soil fertility. *Outlook on Agriculture* 1996, 25, 3, 187-192.
2. Ørskov ER. (2002) *Trails and Trials in Livestock Research*. IFRU Publication, *Macaulay Institute, Craigiebuckler, Aberdeen, Scotland*, 2002.
3. Devendra, C. (2004) Integrated tree crops - ruminant systems. The potential importance of the oil palm. *Outlk. On Agric.* 2004, 33, 157-166.
4. Sibbald AR. Agroforestry principles - sustainable productivity? *Scottish Forestry* 1999, 53 (1), 18-23.
5. Sibbald AR, Eason WR, McAdam JH. and Hislop AM. The establishment phase of a silvopastoral network experiment in the UK. *Agroforestry Systems* 2001, 39-53.
6. Minh TN, Ly LV and Ørskov ER. Using local ducks to control insects in paddy field and in duck, fish, rice systems and eliminate use of insecticides. *SAREC International meeting. Hue, Vietnam 22-26 March 2003*.

Chapter 32

1. Ruddle R and Zhong F. *Integrated agriculture-aquaculture in South China. The dike-pond system of Zhujiang Delta*, Cambridge University Press, Cambridge, 1988.
2. Zhong G, Wang Z and Wu H. *Lan-water Interactions of the Dike-Pond System*, Presses Universitaires de Namur, Namur, 1997.
3. Deng H. The dyke-pond agro-ecosystem of the Zhujiang (Pearl River) Delta, China. *Arch Hydrobiol Beih Ergeb Limnol* 1987, 28, 421-3.
4. Li CX. *Village Annals of Jiujiang, Nanhai, 1657* (in Chinese).
5. Deng H. Application of dike-pond systems to degraded lands of South China. In Parham WE *et al* (eds), *Improving Degraded Lands: Promising Experiences from South China*, Bishop Museum, Honolulu, 1993 (in Chinese).
6. Fan XP. On the development and management of Chenghai-Raoping Reclamation Area. *Tropical Geography* 1985, 5, 34-43.
7. Ho MW. Dream Farm 2 – story so far. *Science in Society* 31, 40-43, 2006.

Chapter 33

1. Professor George Chan, oneVillage advisor and ecological design consultant, oneVillage Foundation http://www.onevillagefoundation.org/ovf/bio/bio_george_chan.html
2. George L. Chan. What does integrated farming system do? November 2003, reproduced in *Sustainable Communities ZERI-NM*. <http://www.scizerinm.org/chanarticle.html>
3. Prein M. ICLARM contribution No. 1611. Integration of Aquaculture into Crop-Animal Systems in Asia., *Agricultural Systems*, 71pp127-146. Elsevier Science Ltd., Amsterdam The Netherlands, 2001.
4. Nitrification. US Environment Protection Agency. <http://www.epa.gov/safewater/tcr/pdf/nitrification.pdf>
5. Where does nitrous oxide come from? US Environment Protection Agency <http://www.epa.gov/nitrousoxide/sources.html>
6. Hagedorn C. The nitrogen cycle: denitrification. *Environmental microbiology*, Spring 2004 http://soils1.cses.vt.edu/ch/biol_4684/Cycles/Denit.html
7. Smith P, Goulding KW, Smith KA, Powlson DS, Smith JU, Falloon P and Coleman K. Enhancing the carbon sink in European agricultural soils: including trace gas fluxes in estimates of carbon mitigation potential. *Nutrient Cycling in Agroecosystems* 2001, 60, 237-252.
8. Animal manure as a source of greenhouse gas. Transform Compost Systems Ltd. <http://www.transformcompost.com/greenhousegas.html>
9. Methanogenesis. Wikipedia, the free encyclopedia June 2005. <http://en.wikipedia.org/wiki/Methanogenesis>
10. Zhong GF, Wan ZQ, Wu HS. Land-Water Interactions of the Dike-Pond System. Presses Universitaires de Namur and Eco-Technologie de Eaux Continentales, Belgium, 1997.

Chapter 34

1. Ho MW. *The Rainbow and The Worm, The Physics of Organisms*, 2nd ed., World Scientific, Singapore, 1998, reprinted 2000, 2001, 2003, 2005, 2006; 3rd enlarged edition, 2008.
2. Ho MW. Are sustainable economic systems like organisms? In *Evolution, Development and Economics* (P. Koslowski, ed.), Springer-Verlag, Berlin, 1998.
3. Ho MW and Ulanowicz R. Sustainable systems as organisms? *BioSystems* 2005, 39-51.
4. Mshigeni K and Pauli G. Brewing and future. *Yes! A Journal of Positive Futures*, Spring 1997, 41-43.
5. Chan G. Dream Farms. Effective & economic possibilities in applying ecological engineering means to sustainable agriculture & agribusiness. Presentation at ISIS Dream Farm workshop, Kindersley Centre, Berkshire, UK, 21 January 2006. <http://www.i-sis.org.uk/onlinestore/av.php>
6. Ho MW. How to beat climate change and the post fossil fuel economy. Dream Farm II. *Science in Society* 2006, 29, 10-14+51.
7. Ho MW. Bug power. *Science in Society* 2005, 27, 24-25.
8. Cheng S and Logan BE. Sustainable and efficient biohydrogen production via electrohydrogenesis. *PNAS* 2007, 104, 18871-3.
9. Fuel cell. Wikipedia, 7 December 2007, http://en.wikipedia.org/wiki/Fuel_cell
10. Ho MW. Green algae for carbon capture and biodiesel. *Science in Society* 2006, 30, 40-41.
11. "Black is the new green", Emma Marris, *Nature* 442, 625-6, 2006.
12. "The companies and organizations poised to turn garbage into fuel, fertilizer and a means of carbon sequestration", Anne Casselman, *Scientific American.com*, 15 May 2007, <http://www.sciam.com/article.cfm?articleid=911528AD-E7F2-99DF-3DF1B9AD8EF2FC57&chanId=sa025> Ho MW How to be fuel and food rich under climate change, *Science in Society* 31, 37-39, 2006.
13. Ho MW, Bunyard P, Saunders PT, Bravo E and Gala R. *Which Energy?* 2006 ISIS Energy Report, Institute of Science in Society, London, 2006.
14. Ho MW. Biogas bonanza for Third World Development. *Science in Society* 2005, 27, 29.
15. Li K-H, and Ho MW. Biogas China. *Science in Society* 2006. 32, 34-37.
16. Ho MW. Organic waste-powered cars. *Science in Society* 2006, 30, 38-39.
17. Lindberg S. Developing New Markets in Scandinavia, Defra Workshop, Methane to Markets, 29-30 November 2006, Kindersley Centre, Berkshire, http://www.methanetomarkets.org/events/2006/agriculture/ag_nov2906.htm
18. The Anaerobic Digestion Working Paper, May 2007, Defra, www.defra.gov.uk/environment/climatechange/uk/energy/renewablefuel/pdf/ukbio0507-work3.pdf
19. Increasing the Uptake of Anaerobic Digestion, Report of a Workshop held on 3-4 September 2007 at Streatham Court, University of Exeter, <http://www.defra.gov.uk/farm/environment/climate-change/anaerobic-workshop/pdf/071011WorkshopReport.pdf>
20. Waste Strategy for England 2007, Defra, <http://www.defra.gov.uk/ENVIRONMENT/waste/strategy/strategy07/pdf/waste07-strategy.pdf>
21. Gannon B. Key elements of biogas energy systems anaerobic digesters. Biogas Energy Systems. http://www.biogas-energy.com/docs_en/BiogasEnergy.pdf
22. Defra Economics & Statistics, Agricultural quick statistics, <http://statistics.defra.gov.uk/esg/quick/agri.asp>
23. Gazley I and Francis P. UK Material Flow Review, Office for National Statistics, January 2005, http://www.statistics.gov.uk/downloads/theme_environment/UK_material_flows_review_final_report.pdf
24. FAOSTAT Database query, <http://faostat.fao.org/faostat/form?collection=Production.Crops.Primary&Domain=Production&servlet=1&hasbulk=0&version=ext&language=EN>
25. Energy consumption in the UK, Department for Business Enterprise & Regulatory Reform, <http://www.dti.gov.uk/energy/statistics/publications/ecuk/page17658.html>

26. Forster P, Ramaswamy V, Artaxo P, Bernsten T, Betts R, Fahey DW, Haywood J, Lean J, Lowe DC, Myhre G, Nganga J, Prinn R, Raga G, Schulz M and Van Dorland R, 2007: Changes in Atmospheric Constituents and in Radiative Forcing. In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M and Miller HL. eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2007.
27. Annual European Community greenhouse gas inventory 1990-2005 and inventory report 2007 EEA Technical report, No 7/2007
28. Bracmort KS, Beddoes J and Burns RT. Markets, Drivers and Outlets, Presentation at Defra Workshop, Methane to Markets, 29-30 November 2006, Kindersley Centre, Berkshire, http://www.methanetomarkets.org/events/2006/agriculture/ag_nov2906.htm
29. Ho MW. *The Rainbow and the Worm, the Physics of Organisms, 3rd Edition*, World Scientific and Imperial College Press, Singapore and London, 2008.
30. Ho MW. Towards an indigenous Western science: causality in the universe of coherent space-time structures. In *Reassessing the Metaphysical Foundations of Science* (W. Harman, ed.), Noetic Sciences Institute, 1994.
31. Tilman D, Reich PB, Knops J, Wedin D, Mielke T and Lehman C. Diversity and productivity in a long-term grassland experiment. *Science* 2001, 294, 843-5.
32. Ho MW. Energy, productivity and biodiversity. *Science in Society* 2004, 21, 48-49.
33. Brown L. Plan B: Rescuing a Planet under Stress and a Civilization in Trouble, Earth Policy Institute, W.W. Norton & Company, New York, 2003.
34. Brown L. *Outgrowing the Earth, The Food Security Challenge in an Age of Falling Water Tables and Rising Temperatures*, W.W. Norton & C., New York, 2004.
35. Natural Capital Institute, <http://www.naturalcapital.org/>
36. "Buying local worth 400 per cent more" New economics foundation 07.03.05 http://www.neweconomics.org/gen/news_buyinglocalworth400percentmore.aspx
37. Darley J. Farm based alternative energy sources. Plenary lecture. Food Security in an Energy-Scarce World, University College, Dublin, 23-25 June 2005.
38. Douthwaite R. *The Growth Illusion: How Economic Growth Has Enriched the Few, Impoverished the Many and Endangered the Planet*. Green Books, Dartington, 1999.
39. Growth *The Celtic Cancer*, Festa Review number 2, The Foundation for the Economics of Sustainability, Dublin, 2004.

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Sustainable World Global Initiative, launched on the web April 2005,

<http://www.i-sis.org.uk/SustainableWorldInitiativeF.php>. First international conference, held 14/15 July 2005 in UK Parliament, followed by a weekend workshop 21 January 2006, out of which came a proposal for an innovative food and energy self-sufficient 'Dream Farm 2' for demonstration/education/research purposes, and the present definitive report, *Food Futures Now* on sustainable food systems under a new economic model, together with the socio-economic, political and structural changes needed for implementation.



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