6H: CAN ORGANIC FARMING FEED THE WORLD?

Donella Meadows

This article by the late Donella Meadows was written for Organic Gardening Magazine, a US publication. Can Organic Farming Feed the World? Of course, we feel it can and with reading this article we know it can! Several fellow Balaton members helped Dana, supplying data, stories and contacts. It was also published in* The Balaton Bulletin*, the newsletter of The Balaton Group, July 2000.

The current rhetoric

> *If we want to feed the world, we have to spray the countryside with poisonous chemicals. We have to splice fish genes into tomatoes. We have to pour on chemical fertilizers. Organic agriculture is for backyard gardens, not for feeding billions.*

That's what you hear, over and over, in the media, from politicians, from "experts." One of the loudest of those experts is Dennis Avery of the Hudson Institute, who says, over and over, things like this: "*Widespread organic farming is simply not a viable option at this* time*. The first consequence of a global shift to organic farming would be the plowdown of at least six-million square miles of wildlife habitat to make up for the lower yields of organic production.*"[1]

Statements like that drive me crazy. They leap with suspicious speed to a conclusion I am not ready to embrace. They close off options without seriously opening them. They add up to a dictum so common it is developing a nickname: TINA. There Is No Alternative.

TINA statements seem designed to make us swallow just one option (to which, after all, There Is No Alternative). Often it is an option which people are questioning, because, however profitable it might be to some, it imposes costs on others, on the environment, or on the future. Whenever I hear TINA, I start listening very hard, seeking out evidence, and above all looking for Alternatives.

When I listen to those who say we must intensify and bioengineer agriculture to feed the world, I notice that they are making three big assumptions: 1. It will take a lot more food to feed the world. 2. More intensive industrial agriculture can produce a lot more food. 3. Organic farming can't.

But when I look at the evidence, I find little support for any of those claims. In fact we already grow enough food to feed everyone. Industrial agriculture is undermining the resource base by which we do so. If anything can restore that resource base and feed the human population over the long term, it seems to be organic farming.

Here's a summary of the evidence:

Will it take more food to feed the world?

About 24,000 of us, mostly children, die every day of causes related to hunger.[2] That's a loss equivalent to 100 fully loaded 747s crashing every day! The UN Food and Agriculture

Organization estimates that 850 million people regularly eat less food than their bodies require.[3] In poor countries one of every three children is malnourished.[4]

And our numbers are growing. By 2030 the United Nations forecasts an increase from the present 6 billion to 9 billion people. Since those people are expected to be more affluent, that could mean a doubled world food demand. Tripled, if the forecast is extended to 2050.[5]

It seems utterly logical that more food is needed right now to feed the hungry and in the future to feed the newcomers. But when you check the facts, you find that the world's farmers already grow enough to feed us all.

The grain produced in the world in 2000 could have sustained 8 billion people if it had been evenly distributed, not fed to animals, and not lost to pests or rot between harvest and consumption.[6] That's grain alone, which constitutes just half the world's food output (measured in calories). Add the annual harvest of tubers, vegetables, fruits, fish, and animal products raised from pasture, and there would be enough to give 6 billion people a full, varied, healthful diet. If we could eliminate post-harvest loss,[7] the population could expand by 25 percent with plenty of food.

With so much food, why is there so much hunger? One answer is that food is monumentally wasted. In the U.S. 70 percent of the grain produced is fed to animals, rather than eaten directly. Worldwide channelling of just one-third of the grain fed to livestock to the hungriest human beings could end death by starvation.[8] Then there are the roughly 600 million of us – one in ten – who are overweight.[9] Consumers in the rich world, overweight or not, could save billions in medical costs, not to mention food costs, if they ate less meat, sugar and fat.

Clearly growing more is not the only way to end hunger. Just look at all the Alternatives:

- Our numbers need not grow so much. Indeed, the UN has been reducing its projections as birth rates drop faster than expected.[10] The global average number of children born per woman has fallen from 5 in the 1950s to 2.7 in the 1990s. Average European family size is 1.4 children.[11] Europe's population is projected to decline from 728 million in 1998 to 715 million in 2025.[12] Birth rates are not a matter of fate; they are a matter of choice

- Growing affluence need not mean unhealthful, wasteful diets. Since healthful eating brings real benefits instead of concocted ones, it would be interesting to see what might happen if moderation, freshness, taste, and health were pushed with the vigor now used to sell grease, sugar and excess

- The food supply could increase as surely by reducing spoilage and waste as by growing more. In the United States alone, 27 percent of the food that reaches stores, restaurants, or homes is thrown out because it is cosmetically imperfect or because it spoils before it is eaten.[13]

If we did save food, would it reach the hungry? Notice that whether we advocate feeding the world by producing more or by wasting less, there's another assumption here: that additional food will reach those who need it. But getting food to the hungry seems to be the problem.

Throughout the Irish potato famine, Ireland exported grain to England. With 200 million hungry people, India exports food and animal feed. Where there is hunger, what seems to be lacking is not food, but *access, right, entitlement* to food – because of war or dislocation or discrimination or hoarding or profiteering or just plain poverty.[14]

People who have no land can grow no food. People who have no money can buy no food. No matter how much food there is.

There's an obvious Alternative here. If we want to feed the world, we should focus not on producing more food but on ways to entitle the hungry to claim the food that is already sufficient to feed us all.

Can more intensive agriculture produce more food?

One could argue that over the past 50 years, beneficence and temperance have grown slowly at best, but food production has tripled. Growing more food we know how to do. Why not do it?

That argument assumes that the ways we've increased food production in the past can be expanded and improved and sustained. The evidence raises some doubt about that.

We are not likely to raise more food by ploughing more land. If there's anything upon which agricultural experts agree, it's that we have reached serious land limits. As the World Resources Institute puts it: "Most high-quality agricultural land is already in production, and the environmental costs of converting remaining forest, grassland, and wetland habitats to cropland are well recognized….Much of the remaining soil is less productive and more fragile."[15] In fact, over the past 30 years global cultivated land area has gone down slightly. Farmland has been lost to development and degradation faster than new land has been brought into production.[16]

But surely we can increase yield – grow more food on each acre.

Forty years ago world average wheat yield was half a ton per acre. Now it is 1.2 tons per acre. French farmers average 3.2. The highest recorded yield on a single farm is 6.4.[17] But in Iran wheat yield is barely 0.5 tons per acre. In India, in spite of the Green Revolution, it is just about 1; in arid, eroded Kazakhstan it is 0.3.[18] There is a similar spread in yields for corn and rice.

Surely those low numbers could be brought up. There may be problematic soils or climates. Farmers may need help seeds, capital, irrigation. But when you see how China's rice yield doubled from 1970 to 1998, or Egypt's corn yield tripled between 1960 and 1990, you have to believe something similar might be done in Kazakhstan and Tanzania.

But how? For how long? And at what cost?

Globally the tripling of grain production over the past 50 years was accompanied by a 20 fold increase in nitrogen fertilizer use.[19] The last doubling of U.S. food output was accomplished with a six-fold increase in fertilizer use and an even greater rise in pesticide applications. The price of high yields, it seems, is the use of synthetic chemicals that bring with them devastating environmental effects.

Wherever soluble synthetic fertilizers are used heavily, there are water problems. Fertilizers don't stay on fields or go only into crops. They run off into streams and leach into groundwater. Nitrate from fertilizer is one of the most common contaminants in drinking water. In U.S. agricultural areas, 22 percent of wells contain nitrate levels that exceed federal safety standards.[20] Where large rivers drain farming regions, they carry into the sea spreading "dead zones," barren of marine life because of agricultural runoff.

To protect water supplies and fisheries, some European countries are mandating fertilizer cutbacks. The city of Munich pays farmers in the watershed that supplies its municipal water to farm only organically – it is cheaper for the city to do that than to build a treatment plant to take agricultural chemicals out of its drinking water.[21]

Pesticides not only weaken the health of farmworkers, and poison wildlife and wells, they also undercut their own effectiveness. They often kill off not only the target pest, but also its natural enemies, creating pest resurgences.[22] Furthermore, regular applications of any pesticide tend to hit individual pests most sensitive to the poison, while letting the least sensitive live and breed. So pest populations become resistant. In the past 50 years over 500 insect pests have become resistant to pesticides, plus 230 crop diseases and 220 weeds.[23]

These and other environmental costs are seldom charged directly or immediately to the intensive farming that seems to produce so much food so cheaply. But they are real costs, paid by someone sooner or later. Some will eventually be paid by farmers, as soil degrades, as water becomes unusable, as pest-control mechanisms fail, or as nations cut fertilizer use to save water resources. If agricultural resources are degraded or if chemical inputs become ineffective, it is not clear that food production can stay as high as it is now, much less go higher.

Especially where it is already highest. Listen to the TINA argument long enough, and you'll notice yet another assumption. The argument for genetic engineering and other means of intensifying food production imply that yields must be higher where they are already high. We need to get still more from those enormously productive Midwest acres. America must feed the world.

When you think about it, that's a curious notion. It must be far simpler and cheaper to raise the corn yield in Tanzania from 0.5 to 1 ton per acre than to raise it in Iowa from 4 to 5. And Tanzania, not Iowa, is where more corn is needed.

The law of diminishing returns says that there must be limits to how much grain or anything else can be coaxed from a given area. Where yields are low, a bit of nutrient, some timely weeding, some pest control can make a big difference. But where yields are high, pushing them higher becomes difficult and eventually impossible.[24]

It appears that intensive agriculture is reaching that point. Average yields are still going up, but the highest yields are not. Says Kenneth S. Cassman, an agronomist at the University of Nebraska: "*It's a striking pattern. Steady progress upward on the average, but at the top – the best of the best – it doesn't appear that maize yields have changed in 25 years….. But the investment in maize-breeding research has gone up four-fold. When every step forward is harder to take, that's a sign of diminishing returns.*"[25]

There is an Alternative to the TINA mandate of pushing nature harder, especially where she has already been pushed too hard. Back off a bit. Heal the soils and the waters along with the chronic surpluses that depress farm prices in the most productive places. If more food is needed, let the world feed the world. Increase yields where there is room for improvement. Since the farmers in those places are poor, help them use inputs that don't need to be bought and that don't undermine soils and waters and human health.

Which is precisely where organic farming comes in.

Can organic farming produce enough?

The TINA folks seem to have fixed in their heads the notion that organic means low yield. I don't know where they get that idea. Maybe they are looking backward at pre-industrial farming, instead of at the performance of modern organic farms.

For example, at the Rodale Institute in Kutztown, Pennsylvania, three kinds of experimental plots have been tested side by side for 15 years. One is a standard high-intensity rotation of corn and soybeans, using commercial fertilizers and pesticides. Another is an organic system that adds a rotation of grass/legume forage, fed to cows. The cow manure is returned to the land. The third is an organic "cash-grain" rotation assuming no animals and no manure. Soil fertility is maintained with legume plow-downs. All three kinds of plots are equally profitable in market terms. Corn yields differ by less than one percent. The rotation with manure far surpasses the other two in building soil organic matter and nitrogen and it leaches less nutrient into groundwater.[26]

It must be noted, however, that the organic rotations include a forage crop as well as corn and beans. So, though corn yield is equally high, corn covers half of the corn/bean rotation but only a third of the corn/bean/forage rotation. You can argue that that means a lower yield of corn. Or you can argue that the forage in the organic rotation is fed to cows instead of corn. Keeping cows and forage on the farm solves two big problems: the soil degradation caused by growing all the grain in one place and the manure pollution caused by feeding all the cows in another place.

In what must be the longest-running organic trial in the world – 150 years! – the Rothamstead Experimental Station in England reports wheat yields on manured plots of 1.58 tons/acre, as opposed to 1.55 tons for plots receiving synthetic fertilizers. Soil organic matter builds up six times higher on the manured plots.[27] Again, the organic system assumes some acreage somewhere feeding cows to provide manure. The fertilized plots assume some fertilizer plant somewhere consuming fossil fuels and emitting greenhouse gases.

In 1989 the National Research Council wrote up eight case studies of organic farms, ranging from a 400 acre grain/livestock farm in Ohio to 1400 acres of grapes in California and Arizona.[28] Their yields were generally equal to or better than the average of the conventional, high-intensity farms surrounding them.

A visible, vocal organic farmer, Fred Kirschenmann of North Dakota, saw his yields plummet when in 1977 he abruptly eliminated all fertilizers and pesticides from his 3100 acre farm. However, after years of experience and organic soil building, he now gets yields as high as the highest of his conventional neighbors - except during droughts, when his humus-rich soil retains moisture much better and his yields are much higher.[29]

Consultants to German farms converting to organic practice have learned that an initial drop in yield is not necessary, if crop rotations are started not with a grain crop but with a leguminous green manure crop.[30]

Biodynamic farms in New Zealand had better soil structure than their conventional neighbors, had better aeration and drainage, were more easily tilled, had higher organic matter and nitrogen content and were equally profitable.[31]

An extensive literature review of dozens of studies carried out on Midwest grain and soybean farms[32] shows a complex picture:

- An early study (in 1978) found organic yields were 11 percent lower
- Another in 1981 found corn yield 18 percent lower, soybean yield the same, and oat yield 6 percent higher
- A 10-year University of Iowa study showed corn yield in an organic corn-oats-alfalfa rotation was only 80 percent of that in a conventional corn-soybean rotation. (How to compare the value of the oats and alfalfa with that of the soybeans is not clear)
- A 1996 study of two South Dakota farms showed similar corn yields for organic and conventional, but higher soybean yields for the conventional farm.

After digesting these and many other studies, the author concludes, "*What is most surprising is how well the organic systems performed despite the minimal amount of research that traditional agricultural research institutions have devoted to them*".

What I conclude after reading a thick folder of articles about organic yields is this: there is no reason to expect them to be low. After a few years of practicing organic methods, and with little outside help, many farmers have come close to duplicating the high yields achieved by the world's most intensive farmers, who have been supported by decades of research. At the same time the organic methods repair much of the environmental damage caused by the chemicals. Since overproduction is a chronic problem in the high-yielding world, why worry if organic methods produce only 80 or 90 percent or so of yields that have probably been pushed up higher than nature can sustain? (Or maybe it will be discovered, once organic farmers restore the soils, that nature actually can sustain those highest of yields – as happens on the best organic farms already).

But high-yield places are not where food is needed. Intensive farms are not the proper basis of comparison to discover whether organic farming can feed the world. Where hunger is endemic and yields are low, where soils are thin and the climate dry, organic methods can boost resources and raise yields using inputs that farmers can afford. I see no reason why, given the high yields organic farming produces in the hands of U.S. farmers, it could not produce yields that would overjoy farmers in the hungry parts of the world. And indeed it is already doing so.

So in conclusion…

Industrial agriculture employs high technology and expensive inputs, extracts high yields from a degrading resource base, sells to people at ever-greater distances, but only to people with money to buy. It has not managed, for the roughly 100 years of its development, to feed the world. It is not cost-effective if all its costs, including those born by farmers, neighbors, communities, and nature, are counted. Its highest yields are not likely to get higher; in fact they are unlikely to be sustained.

Organic agriculture builds nutrients and controls pests through natural methods, which may be ecologically sophisticated, but are largely free. Organic farmers purchase few expensive inputs but recycle many biological wastes. They can produce high, though perhaps not highest, yields, and those yields appear to be more stable with variable weather than those of industrial agriculture. Where organic farming is practiced, it is profitable. It regenerates soil and water resources. It can be adopted without requiring people to import fertilizers or pesticides, to don rubber suits to spray dangerous chemicals in the tropics, or to employ labs to split genes.

Whether we ever feed the world depends more on our willingness to share, to care, to commit to the health of ourselves, our neighbors and our planet, than on our ability to make breakthroughs in genetic engineering or pesticide chemistry. There Are Many Alternatives. Ending hunger seems to me to be a totally possible, wildly desirable, morally essential goal. Ending hunger forever means doing it in a way that restores and regenerates the health of soils, waters, natural ecosystems, farmers and farming communities.

I don't see that industrial agriculture can do the job. But it sure looks to me as if organic farming can.

EXAMPLES OF ORGANIC AGRICULTURE HELPING TO FEED THE WORLD

Crops in southern Benin were failing because of the exhaustion of soil nutrients and the encroachment of an aggressive weed called imperata. Government researchers tested and then spread to 100,000 farmers the practice of planting velvetbean (called *mucuna* in that part of Africa) as a cover crop, to be rotated with maize. The mucuna fixes nitrogen in the soil, adds humus and water-holding capacity when plowed down, and suppresses the imperata weed. Much less labor for weeding is required. Maize yields tripled without purchased nitrogen fertilizer.

The Association for Better Land Husbandry in Kenya worked in 26 communities to teach organic methods with "near nil investment" – because poor farmers could not afford expensive inputs. The focus was on double-dug beds, composting, and use of green and animal manures. In one year the percentage of households free from hunger through the entire year rose from 43 to 75. The proportion buying vegetables fell from 85 to 11 percent; the proportion selling vegetables grew from 20 to 77 percent. The number of households self-sufficient in maize (the staple grain) doubled.

Mountainous Lesotho in southern Africa is severely affected by erosion; its crop yields have fallen in half since 1970. Dr J. J. Machobane, an agronomist there, experimented on his own land and then spread the "Machobane approach" to 2000 farmers. They use standard organic techniques such as intercropping, rotation of legumes with cereals, return of ash and manure to the soil, and use of natural enemies to control pests. Adopting households have tripled yields, have gained cash income from selling produce, and find, for the first time in their experience, that their fields stay green during droughts.[33]

Indonesia's "miracle rice" fields were decimated with a pest that had never been a problem before. The brown plant hopper was reducing the nation's rice output by a quantity that would feed 2.5 million people. Entomologist Peter Kenmore noticed that the infestation was worst on the fields where the most pesticides had been used. The chemicals killed off the natural enemies of the plant hopper. He cut pesticide use by half, and rice yield went up. Indonesia subsequently banned 57 rice pesticides and trained farmers in integrated pest management. Average yield increased and the nation saved $120 million in pesticide imports. Fish, which had disappeared from the streams near the rice paddies, reappeared to supplement the protein diet of the rural people.[34]

When the Soviet government fell in 1990, half of Cuba's food supply disappeared. Cuba had been exporting sugar to Russia in exchange for grain, meat, dairy products, and the chemical fertilizers and pesticides needed to grow the sugar. Since it was under embargo by the West, Cuba's ability to import food, chemicals and petroleum, was essentially cut off. Farmers had no choice but to turn to organic farming. Fortunately, Cuba, with two percent of Latin America's population, has eleven percent of its scientists, and many of them had been studying methods of natural pest control. Now the nation has 218 biocontrol centers, spread throughout farming regions. They monitor pest outbreaks and breed and release natural enemies. Against all odds, with almost no chemical fertilizers or pesticides, Cuba's food supply is slowly rising to what it was before the crisis of 1990. Though luxury foods are not abundant, no one is hungry, and there is reported to be much less sickness among agricultural workers.[35]

Discussion notes

- There are a few gratuitous comments about genetic engineering, e.g. "*It* (organic farming) *can be adopted without requiring people to ……employ labs to split genes".* While not discounting the very real dangers of genetic engineering, there appear to be some real potential gains to be made from it which will reduce hunger and disease in poorer countries. For example, "*labs to split genes"* may see the development of rice varieties containing vitamin A, or rice that needs much less water. Given that three billion people are likely to face severe water shortages within a generation, this latter advance may well be critical
- The philosophy of the paper is not opposed to genetic engineering as such. Rather it argues that the emphasis on it is wrong. Donella Meadows may have responded that organic farming CAN save the world with minimal risk – so let's hasten slowly and cautiously, adopting the precautionary principle
- A worldwide shift to organic farming will require a massive education campaign directed towards Agriculture Ministries in many countries to persuade them that this is a viable alternative to industrial agriculture. Marshalling the support of local farmers, together with providing subsidies to overcome a possible drop in productivity during the transition phase will also be necessary. A major obstacle to be overcome during this transition will be the vested interests of multinational chemical companies and their profits from inorganic fertiliser, herbicide and pesticide manufacture
- The infamous case of the export of grain from Ireland to Britain during the Irish Potato Famine is reflected in the modern world by many undernourished developing countries having to export food to pay for the interest on World Bank development loans. This illustrates the point that the human species is still beset by ancient tribal rivalries which maintain and foster inequities in economic power and resource use. Reduction of these inequities and a more cooperative attitude towards the vital need to achieve sustainability of global soil and water systems is likely to be an essential pre-requisite for the survival of the human species
- To enable organic farming to feed the world – indeed to enable the world to be fed – we will have to realise that locally grown food is essential for a truly sustainable future.

Footnotes

1. Dennis Avery, "The Hidden Dangers in Organic Food," *The American Prospect*, Fall, 1998, pp 19-22.

2. This number is very hard to estimate; children who die from hunger-related causes are not the central focus of government statistical offices. The estimate quoted here was calculated by The Hunger Project, based on worldwide child death statistics and a statement by UNICEF that half of all child deaths can be attributed to hunger. In 1977 the daily hunger death toll was 41,000, by 1987 it had declined to 35,000; it was revised downward again to 24,000 in 1999.

3. U.N. Food and Agriculture Organization, *The Sixth World Food Survey*, Rome, 1996.

4. P. Pinstrup-Anderson, R. Pandya-Lorch and M. W. Rosengrant, 1997, *The World Food Situation: Recent Developments, Emerging Issues, and Long-Term Prospects*, Washington DC, International Food Policy Research Institute, 1997.

5. See, for example, Paul Ehrlich and Anne Ehrlich, *The Stork and the Plow,* New York, G.P. Putnam's, 1995, p.203; and Gretchen Daily et al., "Food Production, Population Growth and the Environment," *Science*, vol. 281, 28 August 1998, p.1291. These numbers are cited over and over in the media. We cannot find an official source for them. FAO food demand forecasts are carried out country by country, and we haven't had the stamina to add them all up. The closest we can come to an FAO source is: "Food Requirements and Population Growth," World Food Summit, Technical Background Document #4, Volume 1, FAO 1996. (www.fao.org/wfs/final/e/volume1/14-e.htm)

6. Calculated by me assuming a subsistence need of 230 kg grain per person per year.

7. Actual postharvest loss varies by crop and place, ranging from 10 to 40 percent, World Resources Institute, *World Resources 1998-99,* New York, Oxford University Press, 1998, p.155.

8. U.N. Food and Agriculture Organization, "Food for All," published for the World Food Summit, 13-17 November 1996.p.13. (www.fao.org/wfs/wfsbook/e/ffa01-e.htm)

9. Gary Gardiner and Brian Halweil, *Underfed and Overfed: The Global Epidemic Of Malnutrition,* Worldwatch Paper 150, March 2000.

10. UN Population Division, *1998 Revision: World Population Estimates and Projections*, New York, U.N. Department of Economic and Social Affairs, 1998.

11. UN Population Division, 1998 op.cit.

12. Population Reference Bureau, 1998 World Population Data Sheet.

13. World Resources Institute, *World Resources 1998-99,* New York, Oxford University Press, 1998, p.156.

14. Amartya Sen, *Poverty and Famines: An Essay on Entitlements and Deprivation*, New York, Oxford University Press, 1981.
15. World Resources Institute, op.cit, p.152.

16. FAOSTAT database, http://apps.fao.org/cgl-bin/nph-db.pl

17. Top wheat yield

18. FAO Production Yearbooks, various years, plus FAOSTAT, op.cit. Food and Agriculture Organization of the United Nations, *Agriculture and Food Security,* September 1997. For Kazakhstan: Lester Brown, “Can We Raise Grain Yields Fast Enough?” *Worldwatch*, July/August 1997, p.12.

19. Charles R. Frink, Paul E. Wagoner, and Jesse H. Ausubel, “Nitrogen fertilizer: Retrospect and Prospect, *Proceedings of the National Academy of Sciences*, vol. 96, p.1175, February 1999.

20. United States Environmental Protection Agency, *National Water Quality Inventory, 1994 Report to Congress,* EPA Report No. 841-R-95-005, Washington DC, 1995, cited in World Resources Institute, 1998-99 World Resources, p.47.

21. Munich Agenda 21 Committee, private communication.

22. There are hundreds of examples of this phenomenon. For a useful summary, see Consumers Union, *Pest Management at the Crossroads,* Yonkers NY 1996.

23. Lester R. Brown, Michael Renner and Brian Halweil, *Vital Signs 1999,* New York, W.W. Norton, 1999, 24.

24. See Lester R. Brown, “Can We Raise Grain Yields Fast Enough,” *Worldwatch* July/August 1997, p.8.

25. Quote from Charles C. Mann, “Crop Scientists Seek a New Revolution,” *Science,* vol. 238, p.310, 15 January 1999.

26. L.E. Drinkwater, P. Wagoner & M. Sarrantonio, “Legume-based cropping systems have reduced carbon and nitrogen losses,” *Nature*, Vol. 396, 19 November, 1998, p.262. See also the commentary by David Tilman, “The greening of the green revolution, *Nature*, vol. 396, 19 November 1998, p.211.

27. A.E. Johnston in *Long-term Experiments in Agricultural and Ecological Sciences*, (eds. R.A. Leigh and A.E. Johnston), CAB Int., Wallingford UK, 1994, pp. 9-37.

28. National Research Council, *Alternative Agriculture*, Washington DC, National Academy Press, Washington DC, 1989.

29. Frederick Kirschenmann, “Fundamental Strategies of Building Agricultural Sustainability,” *Journal of Soil and Water Conservation*, vol. 46, no. 3, May-June 1991, p.167.

30. Prof. Hardy Vogtmann, University of Kassel, private communication.

31. J.P. Reganold, A.S. Palmere, J.C. Lockhart, A.N. Macgregor, “Soil Quality and Financial Performance of Biodynamic and Conventional Farms in New Zealand,” *Science*, vol. 260, 16 April, 1993, p.344.

32. Rick Welsh, “The Economics of Organic Grain and Soybean Production in the Midwestern United States,” Henry A. Wallace Institute for Alternative Agriculture, May 1999.(www.hawiaa.org/pspr13.htm)

33. African examples taken from Prof. Jules Pretty, Director, Center for Environment and Society, University of Essex, U.K. from a paper prepared for *Environment, Development and Sustainability*, a special issue on Sustainable Agriculture, I have only a preprint version.

34. “Integrated Pest Management in Rice in Indonesia,“ FAO, Jakarta, May 1988; Richard Stone, “Researchers Score Victory over Pesticides – and Pests – in Asia,“ *Science,* vol. 256, 29 May

1992, p. 1272; “IPM in Indonesia has increased rice yields and cut farmers’ costs”, *International Pest Control,* vol. 30, Sept/Oct 1988, p.126)

35. Peter Rosset and Medea Benjamin, *The Greening of the Revolution*, Melbourne, Australia, Ocean Press, 1994; Mac Lawrence, “A Country Goes Organic,” *Timeline*, Jan/Feb 1997; Joel Simon, “An Organic Coup in Cuba?” *The Amicus Journal,* Winter 1997; Christopher Flavin, “Cuba’s Dilemma,” *Worldwatch*, May/June 1997.