The Organic Green Revolution

Tim LaSalle, PhD, CEO Rodale Institute
Paul Hepperly, PhD, Director of Research, Rodale Institute
Amadou Diop, PhD, Director of International Programs, Rodale Institute

Introduction

We can feed the world and must restore ecological health to our planet. To do this we need to launch an Organic Green Revolution – that fundamentally changes the way we grow our food to maximize yield while mitigating climate change, restoring clean water, building soils, and protecting agricultural production during times of drought.

The new Organic Green Revolution will mark a dramatic change, moving from unsustainable, increasingly unaffordable and petroleum-based and toxic fertilizers and pesticides, to organic regenerative farming *systems* that sustain and improve the health of our world population, our soil and our environment.

While feeding the hungry has always been a challenging global issue, the juxtaposition of the food price, fuel price and financial crises of this past year have disproportionately hurt the world's most vulnerable - plunging an additional 77 million people into malnutrition, according to the Food and Agriculture Organization (FAO). Now more than ever before we need a paradigm shift rather than incremental change in the way we grow, buy and eat our food. The Organic Green Revolution provides that needed shift.

Not only can organic agriculture feed the world, according to the UN Environment Programme (UNEP) in a report released in October, it may be the only way we can solve the growing problem of hunger in developing countries. UNEP states that its extensive study "challenges the popular myth that organic agriculture cannot increase agricultural productivity." UNEP reported that organic practices in Africa outperformed industrial, chemical-intensive conventional farming, and also provided environmental benefits such as improved soil fertility, better retention of water and resistance to drought. This analysis of 114 farming projects in 24 African countries found that organic or near-organic practices resulted in a yield increase of more than 100 percent. (UNEP "Organic Agriculture and Food Security in Africa," 2008) Achim Steiner, head of UNEP, said the report "indicates that the potential contribution of organic farming to feeding the world may be far higher than many had supposed."

These conclusions also confirmed findings and recommendations of the recently released report of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) panel, an intergovernmental process supported by over 400 experts under the co-sponsorship of the FAO, GEF, UNDP, UNEP, UNESCO, the World Bank and WHO (issued on 14 April 2008). The IAASTD report stated that "the way the world grows its food will have to change radically to better serve the poor and hungry if the world is to cope with growing population and climate change while avoiding social breakdown and environmental collapse." The authors found that progress in agriculture has reaped very unequal benefits and has come at a high social and environmental cost and food producers should try using "natural processes" like crop rotation and organic fertilizers. The authors call for more attention to small-scale farmers and utilization of sustainable agricultural practices, specifically mentioning organic farming as an option several times.

Not only can organic agriculture feed the world, according to the UN Environment Programme (UNEP) in a report released in October, it may be the only way we can solve the growing problem of hunger in developing countries.

The industrial Green Revolution has not, and cannot, feed the world. Instead of helping people feed themselves, it has created a cycle of dependency. In a world of 6.5 billion people, some 923 million people are seriously undernourished (FAO SOFI Report 2007) with more than two billion people suffering from micronutrient malnutrition, or 'hidden hunger' caused by inadequate and non-diversified diets (FAO SOFI Report 2002). 25,000 men, women and children die each day from starvation (World Health Report 2000). Experts project that the world food supply will need to double again over the next 40 years to feed our planet's population.

Based upon the heavy use of chemical fertilizers and irrigation, the industrial Green Revolution worked only as long as fuel was cheap and water was abundant. The transitory benefits of increased short-term food production have come at too great an ecological price as carbon is extracted from the soil and emitted as global-warming carbon dioxide in our air instead of remaining in the soil to nurture crops. Petroleum-based fertilizers and chemical pesticides have also polluted our water and poisoned our environment, food, and people.

Fortunately, the latest scientific approaches in organic agriculture, supported by a body of replicated research data and economic analyses, offer affordable and quickly adaptable ways to implement farming systems that can quickly move us out of our current crisis.

Section One: Regenerative Organic Farming—The True Green Revolution

Organic farming methods are *regenerative* because they restore nutrients and carbon to the soil, resulting in higher nutrient density in crops and increased yields. Organic regenerative farming practices are designed to integrate agro-ecological systems and biological processes, ultimately fueled by the sun.

A regenerative system improves the capacity of the farming systems we are using. When properly managed with respect to local conditions, a natural, organic system will:

- Increase global yields.
- Improve adaptability to climate change by improving drought and flood resistance.
- Empower the world's poorest farmers through a sustainable system that does not depend on unaffordable chemical and petroleum-based inputs.
- Increase the carbon content of the soil, thereby improving its quality and capacity.
- Promote human health and well-being through greater access to more nutrient-dense food from a wider variety of crops.

By contrast, chemically-based degenerative farming systems lead to declines in resource abundance and environmental quality, leaving natural systems in worse shape than they were originally by depleting soils and damaging the environment. Because regenerative organic agriculture uses local and regional resources in natural systems, even small-scale farmers can be self-sufficient – a great benefit to the farmers and their local customers seeking fresh, nutritious food.

Conventional Green Revolution practices using petroleum-based and chemical inputs have been shown to cause continual loss of soil nutrients, soil organic matter and food nutrient content. These practices consume vast quantities of natural resources to prepare, distribute, and apply fossil fuel inputs, and can justly be defined as degenerative farming. With increased population pressures and declining ecological support systems of healthy soil and water, the only sustainable and restorative option available is one based on the biologically-enhancing production models of organic farming.

Some of the conclusions from the October 2008 UNEP report included:

- Organic practices resulted in per hectare food crop productivity increases.
- Organic production allows farmers access to markets, enabling them to obtain premium prices for their produce, as well as increased access to good quality, organic food for the entire community.
- Organic and near-organic agricultural methods and technologies are ideally suited for many poor, marginalized smallholder farmers in Africa or other developing nations.
- Recent food-price hikes and rising fuel prices have highlighted the importance of making agriculture less energy- and external-input dependent.
- Certified organic production for the export market, with its premium prices, can undoubtedly reduce poverty among farmers.
- Organic agricultural systems are making a significant contribution to the reduction of food insecurity and poverty and improvement in rural livelihoods in areas of Africa.

Section Two: Economic Sustainability of Organic Farming Systems

Organic agriculture currently covers 31 million hectares (76.6 million acres) of cultivated land worldwide plus 62 million hectares (153.2 million acres) of certified wild harvest areas. (IFOAM 2007)

Meta-analysis, a compilation and review of scientific literature, reveals that the yields from organic farming in developed countries are about the same as the yields from conventional agriculture. Furthermore, in some university-based research studies comparing conventional and organic practices, yields for organic production are slightly higher.

Such results reflect poorly on conventional agriculture. In conventional agriculture, the soil organic matter and microbiology have not been built back up to where their true potential can be assessed. In addition, these trials are often carried out by staff inexperienced in the application of organic practices in their region. (Transitioning and organic farmers often note that good organic production practices usually require time to navigate a learning curve and develop an understanding of local soils and climates.)

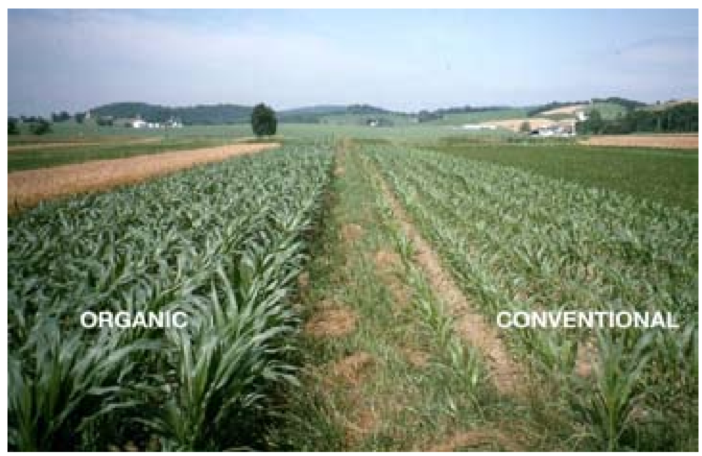
In the developing world, organic yields vastly surpass yields from conventional agriculture by ratios of nearly 1.6 to 4.00. Worldwide across all foodstuffs, organic ratios outperform conventional agriculture by 1:3.

Additional research studies and reports include a large-scale and comprehensive examination of yield data from 286 farms in 57 countries. The data show that small farmers increased their crop yields by an average of 79% by using environmentally sustainable techniques including organic farming and crop rotation. (Pretty et al. 2006)
Another study of agriculture in the developing world showed that organic methods were two to three times more productive than conventional methods. Organic crop rotations that were well-managed resulted in higher yields than Green Revolution industrial methods that also included crop rotations. **The researchers concluded that organic farming can produce enough food to feed the world without increasing the agricultural land base.** (Badgley et al. 2007)

In the United States, many peer reviewed studies show increases in yields of organic production as well. An eight-year comparison study of organic and conventional fruit and vegetable production conducted by the UC Davis Sustainable Agriculture Farming Systems (SAFS) project showed that yields from organic systems were comparable to or better than yields from conventional, fossil-fuel based systems. (Clark, S. 1999)

With the evidence of the benefits and market viability of organic farming well-established, and the environmental damage from conventional farming so clearly threatening global security, the obvious question is not whether regenerative organic farming can produce yields comparable to conventional agricultural methods. Instead, we must ask, where is the leadership and political will to implement the agricultural policy and practice that can feed the world?

In Rodale Institute's Farming Systems Trial® (FST) – the longest running side by side research study of organic and conventional methods – researchers have found that organically-grown corn and soybeans are more resistant to drought, outperforming conventional crops by 30% and 50% -100% respectively. Under organic farming, the soil organic matter captures and retains more water in the crop root zone. Water capture in organic fields can also be 100% higher than in conventional fields during torrential rains. The resilience of organic fields in both extremely wet and extremely dry weather conditions speaks to its capability to create more food security in the climate crisis of erratic and extreme weather. (Lotter et al. 2003).



Better water infiltration, retention and delivery to plants helps to sustain yield during drought.

Delate et al. (2003) reviewed numerous scientific studies conducted throughout the U.S. between 1985 and 1993, and reported that yields and overall economic returns in organic farming systems demonstrate their economic viability. Yields from organic systems were equal to or higher than yields from conventional systems, and organic systems performed consistently better in drought years.

The same study reports that corn and soybean returns from organic systems at the Neely-Kinyon Long-Term Agroecological Research site in Iowa, measured over a three-year period, were significantly greater than returns in conventional corn and soybean crop rotations. The organic rotations were more economical even when market-based organic premiums were excluded from the analysis. "Returns to land, labor, and management were higher in the organic rotations regardless of whether an organic price premium was received or not." (Delate et al. 2003)

Even though less than one percent of agricultural research dollars are spent to study organic production practices, an evaluation of scientifically replicated research from seven major state universities, the Rodale Institute, and the Michael Fields Agricultural Institute shows that in a total of 154 growing seasons, organically produced crops yielded 95% as much as crops grown under conventional high-input conditions (Liebhardt 2001). “Yield data just by itself makes the case for a focused and persistent move to regenerative organic farming systems,” said Dr. Tim LaSalle, CEO of the Rodale Institute. “When we also consider that organic systems are building the health of the soil, sequestering CO2, cleaning up the waterways, and returning more economic yield to the farmer, the argument for an Organic Green Revolution becomes overwhelming.”

With the evidence of the benefits and market viability of organic farming well-established, and the environmental damage from conventional farming so clearly threatening global security, the obvious question is not whether regenerative organic farming can produce yields comparable to conventional agricultural methods. Instead, we must ask, where is the leadership and political will to implement the agricultural policy and practice that can feed the world?

Section Three: Green Revolution Production Benefits Have Declined and Societal Costs Increased

The old Green Revolution was never very green. Since the 1940s, the fossil fuel-based Green Revolution has greatly increased the production of a few selected commodity grain crops such as wheat, corn, soybeans and rice, achieved through high-input, monoculture cropping practices. The unintended consequence of this Green Revolution experiment is that the focus on chemical crop fertility inputs, pest protection, and weed control has increased toxicity in the environment and degraded the planet’s finite soil and water resources (Khan et al. 2007).

Worldwide, 1.9 billion hectares are significantly degraded. Soils are less fertile, erosion has greatly increased, and breakdowns in agro-ecological functions have resulted in poor crop yields, land abandonment, and deforestation. (IAASTD 2008)

Furthermore, chemically-based conventional farming methods lead to human health risks.
Pesticides have damaged wildlife, poisoned farm workers, and created long-term health problems such as cancers and birth defects (Lichtenberg, 1992). Even in the U.S., more than half of the nation’s drinking water wells contained detectable amounts of nitrate and seven percent have detectable amounts of pesticides. (US EPA 1992)

There is a significant health risk from pesticide residue on the foods we eat. Conventionally grown food in the heavily regulated United States has 2/3 more pesticide residue than organically grown food. As soils on organic farming systems continually rid themselves of pesticides from prior industrial agricultural practices, the pesticide residue gap between conventional and organic will grow even larger. (Delate et al. 2006; Baker et al. 2002). Preschool children in the Pacific Northwest eating a conventional food diet had eight times the organophosphorus pesticide exposure compared to children of parents who provided organic diets. (Curl et al. 2003; Lu et al. 2005) In countries with little or no regulatory enforcement, the situation of people eating food contaminated with pesticide residue can be much worse.

A 2008 research review – commissioned in partnership with the United Nations and prepared by 400 world experts and signed by 57 nations – strongly rejects industrial farming as a viable approach to address problems of soaring food prices, hunger, social injustice and environmental degradation in the developing world. (IAASTD 2008). Around the world, one- to five-million farm workers are estimated to suffer pesticide poisoning every year, and at least 20,000 die annually from exposure, many of them in developing countries. (World Bank: Bangladesh: Overusing Pesticides in Farming January 9, 2007)

The United States is burdened with an estimated $12 billion annual health and environmental cost from pesticide use, (Pimentel et al. 2005) and estimated annual public and environmental health costs related to soil erosion of about $45 billion (Pimentel et al. 1995). But the damage transcends environmental soil loss. What cannot be economically calculated is the cost of destroying future generations' ability to produce enough food for their survival.

When all costs are calculated the Green Revolution is not cost-efficient. While centralized, industrial agricultural methods reduce labor costs by substituting herbicides, insecticides and synthetically-produced fertilizers as well as farm machinery for application and crop maintenance, the energy costs are much higher than in organic farming systems. A study of Rodale Institute's FST from 1981 to 2002 shows that fossil energy inputs for organic corn production were about 30% lower than for conventionally produced corn. (Pimentel et al. 2005; Pimentel 2006)

The negative consequences of the Green Revolution led the 2008 United Nations research review to strongly reject industrial farming as a viable approach to address problems of soaring food prices, hunger, social injustice and environmental degradation in the developing world. (IAASTD 2008)

Section Four: Soil Health—The Heart of the Matter

Feeding the world – the attainable goal of an Organic Green Revolution – requires a commitment to thoughtful, science-based systems that produce sustainable food supplies, and, at the same time, help to stabilize the global climate while also restoring clean and safe water supplies. All of these goals depend upon soil quality.

Chemically depleted soil on the left VS nutrient-rich organic soil on the right.

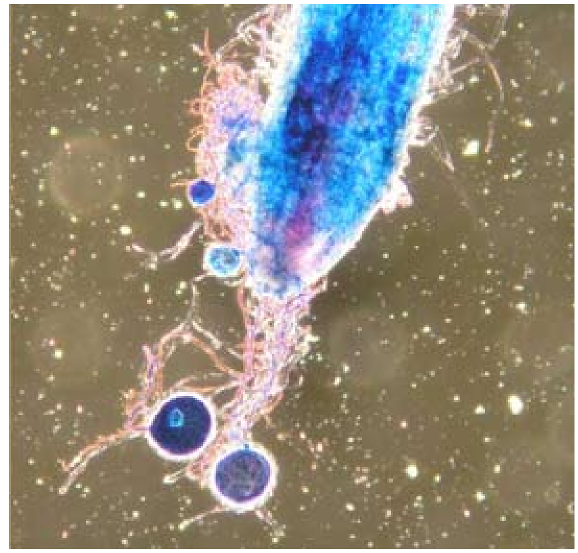
Analysis of the nation's oldest continuous cropping test plots in Illinois shows that, contrary to long-held beliefs, nitrogen fertilization does not build up soil organic matter. (Khan 2007) Plant fertility science expounded by organic farmers and researchers emphasizes the entirety of the soil – rather than simple chemical salts.

The problem is that agricultural erosion through overuse, undernourishment, and chemical inputs that damage the natural, healthy and helpful biological activity in the soil has overwhelmed nature's soil productive capacity. The net result has been the shrinking of our global soil resource base and degradation of our natural resources.

Biologically alive soil provides more structure, preventing erosion; more permeability and aeration for healthier microorganism growth; and more availability of nutrients that are vital for healthy plant growth and productivity. Regenerative systems that feed the soil are the best agricultural strategy.

Dedicating their September issue to soil and its health as one of the most critical issues facing our globe, National Geographic wrote: "Unfortunately, compaction is just one, relatively small piece in a mosaic of interrelated problems afflicting soils all over the planet. In the developing world, far more arable land is being lost to human-induced erosion and desertification, directly affecting the lives of 250 million people. In the first - and still the most comprehensive - study of global soil misuse, scientists at the International Soil Reference and Information Centre (ISRIC) in the Netherlands estimated in 1991 that humankind has degraded more than 7.5 million square miles of land. Our species, in other words, is rapidly trashing an area the size of the United States and Canada combined." They later added, "Connoisseurs of human fecklessness will appreciate that even as humankind is ratcheting up its demands on soil, we are destroying it faster than ever before." "Taking the long view, we are running out of dirt," says David R. Montgomery, a geologist at the University of Washington in Seattle.

Organic matter, combined with glomalin, a secretion from mycorrhizal fungi, is the glue that holds soil in place so it doesn't wash or blow away. Once the mycorrhizi are killed or inhibited and the carbon (soil organic matter) is mined out of the soil, fertilizer can supply some essential elements, but not micronutrients or the water and air-holding capacity that are crucial for productive agriculture.



Mycorrhizal fungi structures enhance the ability of plant roots to access soil moisture and nutrients, produce stable compounds to sequester carbon dioxide as soil carbon , and slow decay of soil organic compounds.

To halt the loss of organic matter, artificial fertilizers need to be removed from the farming practice and soil needs to be covered year round. Long-term research at Rodale Institute shows that properly managed cover crops (legumes, grains, grasses or mixtures) can provide all the nitrogen needed while reversing the loss of soil organic matter. This organic regenerative approach also builds new soil organic matter creating a much healthier and resilient soil. This is the mechanism that sequesters carbon dioxide from the atmosphere, making organic farming the best strategy for fight global warming available to humankind.

Rodale Institute's FST shows that we can gain about 1,000 pounds of carbon per acre per year with cover cropping and crop rotation under organic management. This is about three to ten times the sustained carbon gain from standard no-till planting for corn or soybeans. FST shows insignificant amounts of carbon are deposited in our conventional tillage corn and soybean rotations with chemical fertilizer and pesticide inputs. (Pimentel et al. 2005) A biological no-till system which combines reduced tillage with intensive cover crops and rotation does an even better job in enhancing creation of soil organic carbon by a level of 3- to 7- fold making conservation tillage a poor stepsister to organic methods. (Hepperly et al. 2008)

Soil organic carbon (SOC) is the key to healthy soil structure and nutrient cycling. Recent research clarifies the value, the need, and the processes that create SOC through a direct biological investment in the soil. Long-term trials comparing organic, standard conventional, and conventional no-till cropping systems in Alabama revealed that organic amendments and cover crops used in these systems have far greater ability to build SOC than either nitrogen fertilizer or conventional no-till practices alone (Sainju et al. 2008). These results are corroborated by the 28-year-long Farming Systems Trial at Rodale Institute (Pimentel et al. 2005)

Rodale's long-term FST also shows that composting allows for much greater accumulation of carbon in soil, up to 2,000 pounds per acre, an equivalent of 3.5 tons of carbon dioxide per acre (see"Regenerative Organic Farming, a Solution to Global Warming" at www.rodaleinstitute.org). Over time, compost also recycles needed nutrients to plants. (Delate and Cambardella, 2004; Miller et al. 2008; Pimentel et al. 2005; Poudel, 2002).

SOC is a reliable predictor of crop yield potential, as higher SOC trends toward higher yields. (Mitchell and Entry 1998) A review of nearly 110 years of yield data from the world's oldest continuous cotton experiment concluded that "higher soil organic matter results in higher crop yields." (Mitchell et al. 2008)

Healthy soil from regenerative organic agriculture systems is the life-giving medium, the 'secret-sauce' for agricultural quality, productivity, restoration of environmental degradation, and human health through more nutrient-dense food.

Section Five: Benefits of the Organic Green Revolution's Regenerative Organic Farming Systems

Organic agricultural practices are established, successfully commercialized, and are applicable in all scale operations as shown by farmers across the United States – from family truck farms to commercial operations of many thousands of acres. Regenerative organic farming system techniques can adapt to any location, make best use of local inputs, and creatively transform waste streams into useful, valuable products. The many proven benefits include:

• **Competitive yields:** In the developing world, organic production systems far out-produce Green Revolution methods; while in the developed world, Organic production systems can compete with conventional production. (See numerous citations in Section Two above.)

• **Improved soil:** Organic production methods increase soil organic matter, water infiltration rates and water holding capacity, making more water available to plants per inch of rainfall received. Soils with less organic matter allow more surface runoff (removing topsoil and nutrients with the water), permit higher surface evaporation, and retain much less water within the soil structure. (Veenstra et al. 2006; Lotter et al. 2003; Pimentel et al. 2005).

• **Money savings:** Regenerative organic farming practices reduce external input costs both locally and globally (i.e., insecticides, herbicides, GMO seed, fungicides, fertilizers), while providing price premiums in the developed world. (Hanson et al. 1997)

• **Energy savings:** Organic agriculture reduces the energy required to produce a crop by 20 to 50 percent. (Azeez 2008; Pimentel et al. 2005). Reduction or elimination of fossil fuel use in agricultural production will soon be crucial in the fight against hunger in a world where fossil fuels are in short supply.

• **Mitigation of global warming:** The Organic Green Revolution is one of the most powerful climate change strategies in the fight against global warming because it has the ability to dramatically mitigate CO2 emissions.

Studies show that cover crops can sequester approximately 1,000 pounds of carbon per acre per year (Pimentel et al. 2005; Veenstra et al. 2006; Teasdale et al. 2007). The addition of compost doubles this amount of sequestered carbon to approximately 2,000 pounds of carbon per acre per year, or the equivalent of over 7000 lbs of CO2 (Reider et al. 2000). If these regenerative organic farming practices are applied to all the world's 3.5 billion tillable acres, close to 40 percent of all global CO2 emissions can be mitigated.

• **Enhanced biodiversity:** Organic systems host a greater diversity of plant species, beneficial insects, and wildlife, thus improving the ecological health of bio-regions. (Douds et al. 2007; Galvez et al. 2001; Buyer and Kaufmann 1997; Doran et al. 1987).

• **Water conservation:** Increasing soil carbon (organic matter) greatly enhances soil moisture retention, making more water available to plants per inch of rainfall received. Soils with less organic matter allow more surface runoff (removing topsoil and nutrients with the water), permit higher surface evaporation, and retain much less water within the soil structure. (Liebig, M., Doran, J. 1999; Lotter et al. 2005; Pimentel et al. 2005; Clark, M. et al. 1998)

• **Improved resiliency to weather variation:** Organic systems produce significantly better yields under drought stress and in wet years, and produce comparable yields in years with favorable weather conditions. (Lotter et al. 2003; Pimentel et al. 2005; Delate and Cambardella 2004) Drought has a major impact on food production, accounting for 60 percent of food emergencies, according to a report from the FAO.

• **Increased food nutrient density:** Organically grown foods often contain more nutrients than conventionally grown foods, benefiting human health. (Asami et al. 2003; Mitchell et al. 2007)

• **Reduced toxic load:** Eliminating petrochemical toxins in farming practices improves the health of food, people who eat that food, and the environment. (Curl et al. 2003; Lu et al. 2005; Michalak et al. 2004; Guillette et al. 1998)

The benefits of regenerative organic farming are scientifically documented and compelling. To provide these available benefits for food security, soil regeneration, and global climate change, we must get Organic Green Revolution farming information and technology to farmers in every nation, so that they can apply these sustainable, low- and local-input techniques with the greatest possible success.

Section Six: Leadership and Action

United Nations Under-Secretary-General John Holmes is calling for a "new Green Revolution…that is agriculturally productive, economically profitable and environmentally sustainable." (Holmes 2008) There are no longer any scientific barriers to an immediate and effective response to this urgent clarion call.

A systematic, sustained, and successful program of regenerative organic farming means following two guiding principles:

> **Principle Number One:** Build soil organic matter through the use of cover crops, crop rotation, and compost.
>
> **Principle Number Two:** Improve ecosystem health and human nutrition through plant and animal biodiversity.

The food, fuel and financial crises have shown us that continuing present agricultural practices is not possible. Holmes also emphasizes that a new Green Revolution cannot wait: "The time to do it is now, before the effects of rising population, more erratic weather, commodity price shocks and depleting fossil fuel resources cause further massive suffering…." (Holmes 2008)

In the United States and other developed countries where chemical agriculture has inserted itself into the policy mechanisms of governments, universities, and common agriculture practices, economic incentives, such as paying farmers and other land managers for the carbon they store rather than the commodities that they produce, are needed in order to trigger significant change in time to head off both the hunger and environmental crises.

The benefits of regenerative organic farming are scientifically documented and compelling. To provide these available benefits for food security, soil regeneration, and global climate change, we must get Organic Green Revolution farming information and technology to farmers in every nation, so that they can apply these sustainable, low- and local-input techniques with the greatest possible success.

Fortunately, we now know how to wean ourselves off of an experimental agricultural system that is unsustainable – and harmful - and that, in the long sweep of history, has been around for barely 75 years. We know how to double our food supply over the next 40 years through organic regenerative farming systems. 923 million people do not need to be hungry. 25,000 men, women and children do not have to die each day from starvation.

Literature Cited

Altieri, M. and Nicholls, C.. 2006. Agroecology and the search for truly Sustainable Agriculture. Berkeley, University of California, USA. 290pp.

Asami, D., Hong, Y., Barrett, D., and A. Mitchell. 2003. Comparison of the total phenolic and ascorbic acid content of freeze-dried and air-dried marionberry, strawberry, and corn using convention organic and sustainable agricultural practices. J. Agric. Food Chem. 57; 1237-1241.

Azeez, G. 2008. The comparative energy efficiency of organic farming. Colloquium on Biologically Based Agriculture and the Climate. Enita Clermont France April 17-18, 2008. 7 pages.

Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M., Aviles-Vazquez, K., Samulon, A., Perfecto, I. 2007. Organic agriculture and the global food supply. Renewable Agriculture and Food Systems: 22(2); 86-108.

Brian, P., Benbrook, C., Groth, E. 2002. Pesticide residues in conventional, IPM-grown and organic foods: Insights from three U.S. data sets. Food Additives and Contaminants, Vol.19, No. 5, 427-446.

Buyer, J., and Kaufman, D. 1997. Microbial diversity in the rhizosphere of corn grown under conventional and low-input systems Applied Soil Ecology 5(1): 21-27.

Clark, S., Klonsky, K., Livingston, P., Temple, S. 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: 109-121.

Clark, S. 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 v. 14(s) 109-121.

Clark, S., Ferris, K. Klonsky, W., Lanini, A., van Bruggen, C., Zalom, F. 1998. Agronomic, economic, and environmental comparison of pest management in conventional and alternative tomato and corn systems in northern California. Agric. Ecosyst. Environ. 68(1–2):51–71.

Curl, C., Fenske, R., and K. Elgethun. 2003. Organophosphorus pesticide exposure of urban and suburban pre-school children with organic and conventional diets. Environ. Health Perspect. 111:377-382.

Delate, K., Turnbull, R., and DeWitt, J. 2006. Measuring and Communicating the Benefits of Organic Foods. Crop Management doi: 10.1094/CM-2006-0921-14-PS.

Delate, K. and C. Cambardella. 2004. Agroecosystem performance during transition to certified organic grain production. Agron J. 96:1288-1298.

Delate, K., M. Duffy, C. Chase, A. Holste, H. Friedrich 2003. An economic comparison of organic and conventional grain crops in a long-term agroecological research (LTAR) site in Iowa. American Journal of Alternative Agriculture Vol. 18(2):59-69. Journal paper No. 19802 of the Iowa Agriculture and Home Economics Expt. Sta., Ames, Iowa. 2003

Doran, J., Fraser, D., Culik, M., and W. Liebhardt. 1987. Influence of alternative and conventional agricultural management on soil microbial processes and nitrogen availability. American Journal of Alternative Agriculture II(3): 99-106.

Dormarr, J, … 1988 [agriculture and Agri-Foods Canada – need precise article info]

Douds, D., Hepperly, P., Seidel, R., and K. Nichols. 2007. Exploring the role of mycorrhizal fungi in carbon sequestration in agricultural soil. American Society of Agronomy Annual Meeting, November, New Orleans, Abstr. 1011.

Food and Agriculture Organization of the United Nations 2002. Annual FAO report, *The State of Food Insecurity in the World (SOFI).*

Food and Agriculture Organization of the United Nations 2007. Annual FAO report, *The State of Food Insecurity in the World (SOFI).*

.
Galvez, L., Douds, D., and P. Wagoner. 2001. Tillage and farming system affect AM fungus formation, and nutrient utilization of winter wheat in a high P soil. American Journal of Alternative Agriculture 16:152-160.

Hanson, J., Lichtenberg, E., and S. Peters. 1997. Organic versus conventional grain production in the mid-Atlantic: An economic overview and farming system overview. American Journal of Alternative Agriculture 12(1):2-9.

Harris, G., Hesterman, O., Paul, E., Peters, S., and R. Janke. 1994. Fate of Legume and Fertilizer Nitrogen-15 in a Long-Term Cropping Systems Experiment. Agronomy Journal 1994, 86:910-915

Ho, M., Burcher, S., Ching, L., et al. 2008. Food Futures Now. Institute of Science in Society (ISIS)

Holmes, J., Oct. 1, 2008 The Washington Times op-ed column.

IAASTD, 2008. International Assessment of Agricultural Knowledge, Science and Technology for Development Global Report.

International Federation of Organic Agriculture Movements (IFOAM),
The World of Organic Agriculture: Statistics and Emerging Trends 2007, http:www.ifoam.org/press/press/Statistics_2007.html

IPPC, 2007. Climate change, 2007. The Fourth IPPC Assessment Report.

Khan, S., Mulvaney, R., Ellsworth, T., and C. Boast. 2007. The myth of nitrogen fertilization for soil carbon sequestration. J. Environ. Qual. 36:1821-1832.

Kotschi, J. and K. Muller-Samann, 2004. The role of organic agriculture in mitigating climate change: a scoping study. IFOAM, Bonn, Germany. 64 pp.

Lichtenberg, E. 1992. Alternative approaches to pesticide regulation. Northeast J. Agric. and Resource Economics 21:83-92.

Liebhardt, W., Andrews, R., Culik, M., Harwood, R., Janke, R., Radke, J., and S. Rieger-Schwartz. 1989. Crop production during conversion from conventional to low-input methods. Agronomy Journal 81(2):150-159

Liebhardt, W. Get the facts straight: Organic agriculture yields are good. Organic Farming Research Foundation Information Bulletin Summer 2001 Number 10.

Liebig, M., Doran, J. 1999. Impact of organic production practices on soil quality indicators. J. Environ. Quality 28(5):1601–1609.

Lotter, D., Seidel, R., and W. Liebhardt. 2003. The performance of organic and conventional cropping systems in an extreme climate year. American Journal of Alternative Agriculture 18(2):1-9.

Lu, C., Toepel, K., Irish, R., Fesnke, R., Barr, D., and R. Bravo. 2005. Organic diets significantly lower children dietary exposure to organophosphorus pesticide. Environ. Health Perspect. 114(2): 260-263.

Mader, P. A. Fliebach, D. Dubois, L. Gunst, P Fried, and U. Niggli, 2002. Soil fertility and biodiversity in organic farming. Science 31. Vol 296, No. 5573. May 2002. pp. 1694-1697.

Michalak, P., C. Ziegler Ulsh, C. Reider, and R. Seidel. 2004. Water, Agriculture, and You. The Rodale Institute.

Miller, P., Buschena, D., Jones, C., and J. Holmes. 2008. Transition from intensive tillage to no tillage and organic diversified annual cropping systems. Agron. J. 100:591-599.

Mitchell, C.C., and J.A. Entry. 1998. Soil C, N and crop yields in Alabama's long-term 'Old Rotation' cotton experiment. Soil Tillage Res. 47:331–338.

Mitchell, A., Hong, Y, Koh, E., Barrett, D., Byrant, D., Denison, R., and S. Kaffka. 2007. Ten year comparison of influence of organic and conventional crop management on contents of flavonoids in tomatoes. J. Agric. Food Chem. 55(15):6154-6159.

Mitchell, C., Delaney, D., and Balkcom, K. 2008. A Historical Summary of Alabama's Old Rotation (circa 1886): The World's Oldest, Continuous Cotton Experiment. Agron J 100: 1493-1498.

Mon, P., and D. Holland. 2006. Organic apples in Washington state: an input-output analysis. Renewable Agriculture and Food Systems 21:134-141.

Moyer, J., Saporito, L., and R. Janke. 1996. Design, Construction, and Installation of an Intact Soil Core Lysimeter. Agronomy Journal 88(2):253-256

Pallant, E., Lansky, D., Rio, J., Jacobs, L., Schuler, G., and W. Whimpenny. 1997. Growth of corn roots under low-input and conventional farming systems. American Journal of Alternative Agriculture 12(4):173-177

Pimentel, D., 2006. Impacts of organic farming on efficiency and energy use in agriculture. www.organicvalley.coop/fileadmin/pdf/ENERGY_SSR.pdf. 40 p.

Pimentel, D., Hepperly, P., Hanson, J., Douds, D., and R. Seidel. 2005. Environmental, energetic, and economic comparisons of Organic and Conventional farming systems. Bioscience 55(7):573-582.

Posner, J., Baldock, J., Hedtcke, J. 2008. Organic and conventional production systems in Wisconsin Integrated Cropping Systems Trials: I. Productivity 1990-2002. Agron. J. 100:253-260.

Poudel, D., Horwath, W., Lanini, W., Temple, S., Van Bruggen, A. 2002. 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 90(2):125-137.

Pretty, J., A. D. Noble, D. Bossio, J. Dixon, R. E. Hine, F. W. T. Penning de Vries, and J. I. L. Morison .2006. Resource-Conserving Agriculture Increases Yields in Developing Countries. Environmental Science and Technology, No. 40, Iss. 4: 1114-1119. www.ecofair-trade.org/pics/en/brosch_ecofairtrade_el.pdf

Puget, P., Lal, R. 2005. Soil organic carbon and nitrogen in a Mollisol in central Ohio as affected by tillage and land use. Soil Tillage Research 80(1/2):201-213.

Reicosky, D. 2001. Influence of tillage on Carbon losses. Power Point World Congress on Conservation Agriculture, Madrid, Spain.

Reider, C., Herdman, W., Drinkwater, L., and R. Janke. 2000. Yields and nutrient budgets under composts, raw dairy manure and mineral fertilizer. Compost Science and Utilization 8(4):328-339.

Sainju, U., Senwo, Z., Nyakatawa, Tazisong, I., Chandra Reddy, K. 2008. Tillage, cropping systems, and nitrogen fertilizer source effects on soil carbon sequestration and fractions. Journal of Environmental Quality 37:880-888.

Stanhill, G. 1990. The comparative productivity of organic agriculture. Agriculture, Ecosystems and Environment. 30: 1–26. 1990.

Teasdale, J., Coffman, C., Mangum, R. 2007. Potential long-term benefits of no-tillage and organic cropping systems for grain production and soil improvement. Agronomy Journal 99, 2007.

Tilman, D., Wedin, D., and Knops, J. 1996. Productivity and sustainability influenced by biodiversity in grassland ecosystems. Nature 379:718-720.

United Nations Environmental Programme (UNEP) and United Nations Conference on Trade and Development (UNCTAD), 2008 “Organic Agriculture and Food Security in Africa”' pages 1-61.

Veenstra, J., Horwath, W., Mitchell, J., Munk, D. 2006. Conservation tillage and cover cropping influences soil properties in San Joaquin Valley cotton-tomato crop. California Agriculture 60(3):146-152.

West, T., and Marland, G. 2002. Net carbon flux from agricultural ecosystems: methodology for full carbon cycle analyses. Environmental Pollution 116(3):439-444.

World Bank: Bangladesh: Overusing Pesticides in Farming January 9, 2007.

World Health Organization 2000. The World Health Report 2000 – Health systems: Improving performance.

Addendum

Rodale Institute: An overview of our work with organic and sustainable farming

Summary

Rodale Institute is located on a 333-acre certified organic farm in Kutztown, Pennsylvania and has spent 60 years doing extensive research to provide farmers with the know-how, tools and techniques they need to succeed, policy-makers the information they need to best support our farmers and consumers with the resources they need to make informed decisions about the food they buy and eat both in the United States and abroad.

From aquaculture and amaranth studies to vetch varietals trials and design and experimentation with a cutting-edge roller-crimper tool for low-cost, low-input no-till, the on-farm and collaborative research of the Rodale Institute has spanned the width and breadth of agriculture. The farm is perhaps best known for its Farming Systems Trial® (FST), the United State's longest-running scientific experiment specifically designed to compare organic and conventional farming practices.

Brief History

The Institute was created by visionary J.I. Rodale who moved from New York in the late 1930s to rural Pennsylvania, where he was able to realize his keen personal interest in farming. He learned about organic food-growing concepts being promoted by Lady Eve Balfour and Sir Albert Howard and theorized, based on their work and his own observations, that to preserve and improve our health we must restore and protect the natural health of the soil. Developing and demonstrating practical methods of rebuilding natural soil fertility became J.I. Rodale's primary goal when World War II's sudden shortage of nitrogen fertilizer – diverted to making munitions – exposed the natural nutrient poverty of the nation's soil. In 1947, J.I. founded the Soil and Health Foundation, forerunner to the Rodale Institute. He also created successful periodicals, including Health Bulletin, Organic Farming and Gardening and Prevention magazines.

The concept of "organic" was simple but revolutionary in the post World War II era. Manure, cover crops and crop mixtures were standard practices through World War I, but chemical fertilizers, pesticides, herbicides, artificial ingredients, preservatives and additives for taste and appearance in the years since the war had rapidly changed agriculture. As J.I. Rodale communicated the idea of creating soil rich in nutrients and free of contaminants, however, people began to listen and acceptance grew.

J.I. Rodale died in 1971. His son Robert expanded the farm and health-related research with the purchase of the 333-acre farm near Kutztown, Pennsylvania. With his wife Ardath, Robert established what is now the Rodale Institute and an era of research began that continues today. Powerful testimony by Robert Rodale, and the farmers and scientists who swore by the sustainable methods pioneered at Rodale, convinced the U.S. Congress to include funds for regenerative agriculture in the 1985 Farm Bill. Today, federal, state and local governments, land-grant universities and other organizations nationwide are pursuing regenerative agriculture research and education programs.

When Robert Rodale was killed in a traffic accident in Moscow in 1990, Ardath Rodale became the Institute chairman and John Haberern became president. In 1999 Robert and Ardath Rodale's son, Anthony became chairman of the board. Anthony and Florence, his wife, developed outreach efforts to children during their period of active program involvement before Anthony became an international ambassador for the Rodale Institute's mission. Board member Paul McGinley became co-chair of the board with Ardath in 2005.

Timothy J. LaSalle became the first CEO of the Institute in July 2007, bringing decades of experience in academic, agricultural and non-profit leadership to the task. Under his guidance, the Institute champions organic solutions for the challenges of global climate change, better nutrition in food, famine prevention and poverty reduction.

TIMELINE

1941 — J.I. Rodale buys a farm near Emmaus, PA to test food-growing concepts promoted by Lady Eve Balfour and Sir Albert Howard.

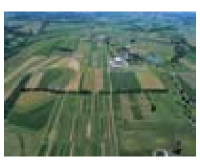
1942 — "Plants are not like money," J.I. noted in the inaugural issue of Organic Farming and Gardening magazine. "A one-dollar bill always means 100 cents. But two different pea pods each representing the same weight do not have the same amount of vitamins."

1947 — Soil and Health Foundation, forerunner to the Rodale Institute, is founded by J.I. Rodale with the goal of developing and demonstrating practical methods of rebuilding natural soil fertility.

1950 — J.I. Rodale speaks about the merits of organiculture (a term he coined in 1948 to describe organic gardening) to the House Select Committee to Investigate the Use of Chemicals in Food.

1954 — "Organics is not a fad'" J.I. writes. "It has been a long-established practice - much more firmly grounded than the current chemical flair. Present agricultural practices are leading us downhill."

1971 — After J.I. Rodale's death, his son Robert and his wife Ardath expand the farm and health-related research with the purchase of a 333-acre farm near Kutztown, Pennsylvania, establishing what is now the Rodale Institute.



1978 — President Jimmy Carter charges Agricultural Secretary Bob Bergland to have USDA ARS personnel study alternative agriculture approaches including organic practices.

1981 — Rodale Institute works with USDA to start the Farming Systems Trial® (FST) studying the transition to organic production and comparing it to conventional agriculture. Robert Rodale first describes regenerative agriculture: "We must go beyond sustainability, to renew and to regenerate our agricultural resources."

1987 — Thanks largely to Robert Rodale's lobbying efforts, Congress passes the first-ever federal sustainable agriculture appropriation-$3.9 million—planting the seeds for the Sustainable Agriculture Research and Education (SARE) and Low Input Sustainable Agriculture (LISA) programs.

1988 — Organic systems from Rodale Institute's Farming Systems Trial® show comparable yield for corn, soybean and small grains in organic compared to conventional production

1990 — Organic Foods Production Act is signed into law as part of the Farm Bill and Robert Rodale dies in a traffic accident in Moscow. Ardath Rodale becomes the Institute chairman and John Haberern becomes president.

1991 — The Rodale Institute sponsors the world's first International Conference on the Assessment and Monitoring of Soil Quality. More than two dozen specialists from five countries participate.

1993 — Rodale Institute's Compost Utilization Trial begins comparing the use of composts, manures and synthetic chemical fertilizer.

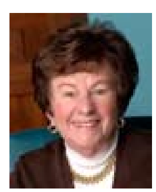
1996 — Rodale Institute's article in Nature shows organic management conserves carbon and nitrogen in the soil promoting productivity. ARS soil scientist Sara F. Wright discovers glomalin, soil "super glue," implicated as a key component of agricultural carbon sequestration.

2002 — Organic systems in Rodale Institute's Farming Systems Trial are shown to have significantly higher yields under severe drought and environmental stresses.

2003 — Rodale Institute research department calculates carbon sequestration in the Farming Systems Trial and develops white paper on the significant impact regenerative farming technique have on mitigating global warming.

2004 — Rodale Institute research department calculates carbon sequestration in the Compost Utilization Trial and finds overwhelming evidence that regenerative farming techniques can become the single largest wedge to actively combating global warming.

2005 — Rodale Institute, Cornell University, Maryland University and USDA ARS show carbon and nitrogen sequestration values, economics and energy efficiency of organic agriculture in Bioscience article. Anthony Rodale becomes chairman emeritus for the Rodale Institute, and Ardath Rodale and Paul McGinely take over as co-chairs.



2006 — University of California Davis shows carbon sequestration levels in San Yoaquin Valley similar to Rodale Institute findings.

2007 — University of Illinois at Morrow Plots shows nitrogen fertilizers do not contribute to carbon sequestration corroborating Rodale Institute Compost Utilization Trial results.

Henry A. Wallace Agricultural Research Center shows that organic farming can yield better soil quality and sequestration results compared to no-till alone.

Timothy J. LaSalle joins the Rodale Institute as the first CEO. Under his leadership, the Institute champions organic solutions for the challenges of global climate change, better nutrition in food, famine prevention and poverty reduction.