



RODALE
INSTITUTE™

THE
FARMING SYSTEMS TRIAL

Celebrating 30 years



OUR MISSION

Through organic leadership we improve the health and well-being of people and the planet.

CORE VALUES

We empower each other to live our mission.

Our farm is a destination for inspiration.

Our research is a catalyst for change.

We are a clear voice for informed choice.



THE FARMING SYSTEMS TRIAL

Celebrating 30 years

03	INTRODUCTION
05	HISTORY
07	SOIL HEALTH
09	YIELDS
13	ECONOMICS
15	ENERGY
17	HUMAN HEALTH
19	WHAT'S THE BIG PICTURE?
21	REFERENCES

INTRODUCTION

The hallmark of a truly sustainable system is its ability to regenerate itself. When it comes to farming, the key to sustainable agriculture is healthy soil, since this is the foundation for present and future growth.

Organic farming is far superior to conventional systems when it comes to building, maintaining and replenishing the health of the soil. For **soil health** alone, organic agriculture is more sustainable than conventional. When one also considers **yields, economic viability, energy usage, and human health**, it's clear that organic farming is sustainable, while current conventional practices are not.

As we face uncertain and extreme weather patterns, growing scarcity and expense of oil, lack of water, and a growing population, we will require farming systems that can adapt, withstand or even mitigate these problems while producing healthy, nourishing food.

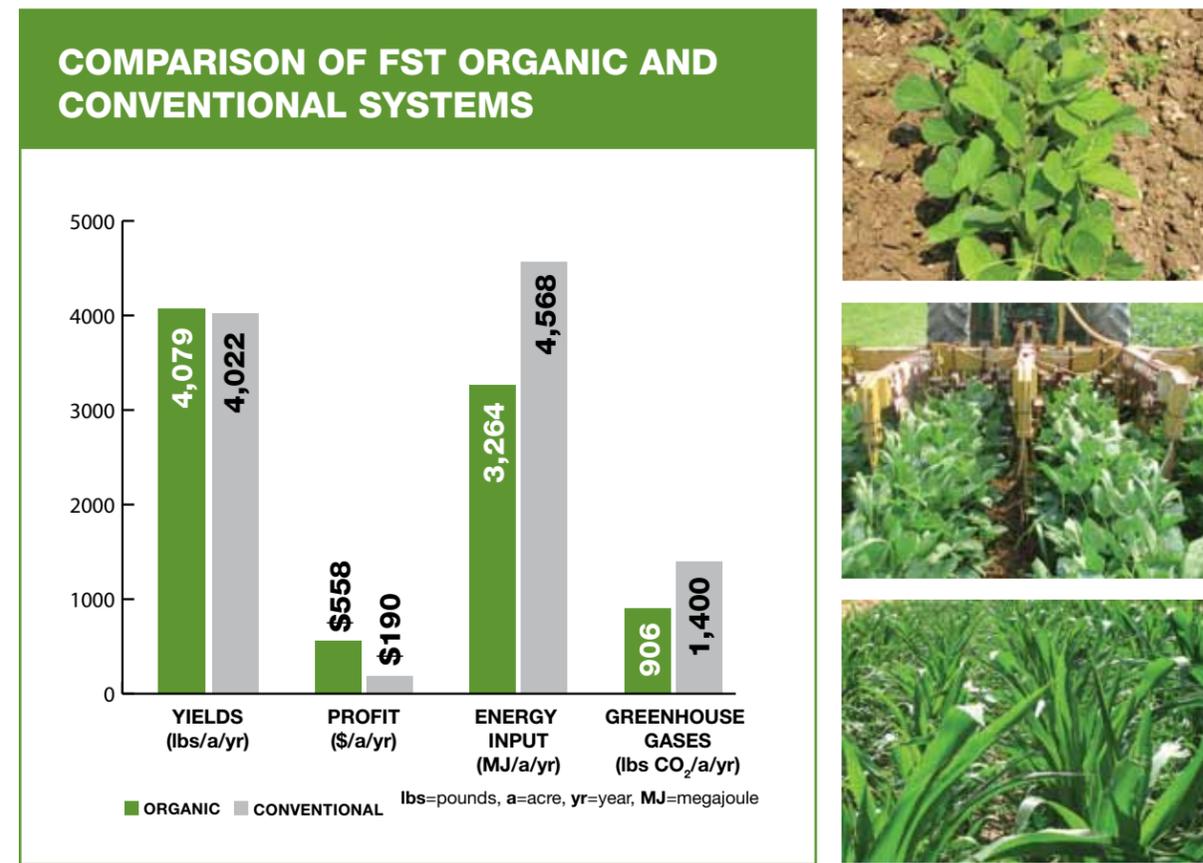
After 30 years of side-by-side research in our Farming Systems Trial (FST)[®], Rodale Institute has demonstrated that organic farming is better equipped to feed us now and well into the ever changing future.



A view of FST

FST FACTS

- Organic yields match conventional yields.
- Organic outperforms conventional in years of drought.
- Organic farming systems build rather than deplete soil organic matter, making it a more sustainable system.
- Organic farming uses 45% less energy and is more efficient.
- Conventional systems produce 40% more greenhouse gases.
- Organic farming systems are more profitable than conventional.



SUSTAINABLE

As it pertains to farming, this term does not have a standard definition. For the purposes of this paper, we will define sustainable as a system that can maintain or enhance soil fertility indefinitely.

ORGANIC

Most simply, this refers to a system of farming that does not use synthetic chemicals and, instead, mimics natural systems. This may encompass different farm sizes, practices and philosophies that, at their core, reject the use of toxic, synthetic chemicals.

HISTORY

The Farming Systems Trial (FST)[®] at Rodale Institute is America's longest running, side-by-side comparison of organic and chemical agriculture. Started in 1981 to study what happens during the transition from chemical to organic agriculture, the FST surprised a food community that still scoffed at organic practices. After an initial decline in yields during the first few years of transition, the organic system soon rebounded to match or surpass the conventional system. Over time, FST became a comparison between the long term potential of the two systems.

We selected corn and soybean production as our research focus because large tracts of land, particularly in our region and the Midwest, are devoted to the production of these crops. Corn and soybean acreage comprised 49% of the total cropland in the U.S. in 2007. Other grains made up 21%, forages 22% and vegetables just 1.5%.

Throughout its long history, the FST has contained three core farming systems, each of which features diverse management practices: a manure-based organic system, a legume-based organic system, and a synthetic input-based conventional system. In the past three years of the trial, genetically modified (GM) crops and no-till treatments were incorporated to better represent farming in America today. Results and comparisons are noted accordingly to reflect this shift.



Aerial photograph of FST field taken in 1981 prior to initial planting.

THE DIFFERENT SYSTEMS



ORGANIC MANURE

This system represents an organic dairy or beef operation. It features a long rotation including both annual feed grain crops and perennial forage crops. The system's fertility is provided by leguminous cover crops and periodic applications of manure or composted manure. This diverse rotation is also the primary line of defense against pests.



ORGANIC LEGUME

This system represents an organic cash grain system. It features a mid-length rotation consisting of annual grain crops and cover crops. The system's sole source of fertility is leguminous cover crops and the rotation provides the primary line of defense against pests.



CONVENTIONAL SYNTHETIC

This system represents the majority of grain farms in the U.S. It relies on synthetic nitrogen for fertility, and weeds are controlled by synthetic herbicides selected by and applied at rates recommended by Penn State University Cooperative Extension. In 2008, genetically modified (GM) corn and soybeans were added to this system.



NO-TILL SYSTEMS

Each of the major systems was divided into two in 2008 to compare traditional tillage with no-till practices. The organic systems utilize our innovative no-till roller/crimper, and the no-till conventional system relies on current, widespread practices of herbicide applications and no-till-specific equipment.

CROP ROTATIONS

The crop rotations in the organic systems are more diverse than in the conventional systems, including up to seven crops in eight years (compared to two conventional crops in two years). While this means that conventional systems produce more corn or soybeans because they occur more often in the rotation, organic systems produce a more diverse array of food and nutrients and are better positioned to produce yields, even in adverse conditions.

SOIL HEALTH

For plants to be healthy, the soil they grow in must be healthy, too. Healthy soil may be defined simply as soil that allows plants to grow to their maximum productivity without disease, fertility or pest problems limiting production, and without a need for unusual supplements or support.

According to the Environmental Working Group and soil scientists at Iowa State University, America's "Corn Belt" is losing precious topsoil up to 12 times faster than government estimates. Over the years, the FST organic systems have exhibited a number of notable improvements the conventional system did not, including soil that regenerates rather than eroding away.

Fertile soil, rich in organic matter and microbes, creates a more stable environment for plants. In times of stress, organically-managed soil has greater ability to provide for crops what the weather has not. The Farming Systems Trial has provided the following insights about soil quality:

■ **Soil health in the organic systems has increased over time while the conventional systems remain essentially unchanged.**

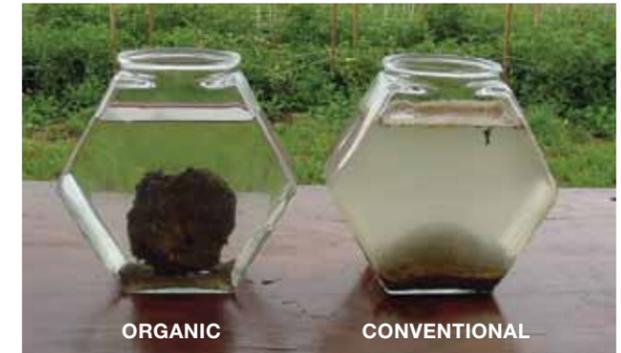
One measure of soil health is the amount of carbon contained in the soil. Carbon performs many crucial functions such as acting as a reservoir of plant nutrients, binding soil particles together, maintaining soil temperature, providing a food source for microbes, binding heavy metals and pesticides, influencing water holding capacity and aeration, and more. More carbon is better!



Soils in the organic and conventional plots are very different in appearance due to the increase in soil organic matter in the organically managed soils. The organically managed soil is darker and aggregates are more visible compared to the conventionally managed soil.

■ **Carbon increase was highest in the organic manure system, followed by the organic legume system. The conventional system has shown a loss in carbon in more recent years.**

■ **Organic fields increased groundwater recharge and reduced runoff.** Water volumes percolating through soil were 15-20% higher in the organic systems than the conventional system. Rather than running off the surface and taking soil with it, rainwater recharges our groundwater reserves in the organic systems, leaving soil in the fields where it belongs.



■ **Soils of the organic systems are better equipped to store and use water efficiently.** This means that plants have what they need "in storage" and can better access those stores.

When nutrients are applied in synthetic forms, they leach or pass through the soil more quickly than nutrients derived from manures, composts, or cover crops, ending up in water sources both above and below ground. In this case, important nutrients are lost from the soil when rain falls, or snow melts, resulting in negative impacts on succeeding crops. **One reason the application of synthetic forms of nutrients (ie: nitrogen, phosphorus, potassium) is problematic is because the nutrients do not remain available to the plants.**

In short, organic soil hangs onto more of its "good stuff" for a longer period of time, while chemical systems can lose the "good stuff" more quickly.



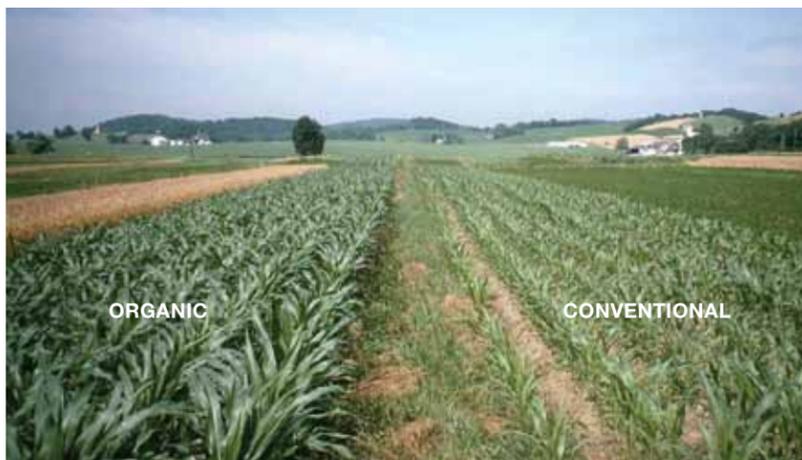
YIELDS

For a system to be sustainable, it needs to be able to feed our global population not just now, or ten years from now, but one hundred years from now—and longer.

Following the three years when the FST fields were being transitioned to organic production, the organic corn fields produced just as much as the conventional fields. And while conventional growers are now battling newly herbicide-resistant superweeds with more powerful chemicals, the FST organic crops hold their own against weeds, producing the same as the conventional fields without the assistance of herbicides.

Another long-term research project out of Iowa mirrors Rodale Institute's work. A 12-year study of organic versus conventional methods found that after the transition period, organic corn and soybeans produced, on average, nearly identically amounts of food as the conventionally-managed plants.

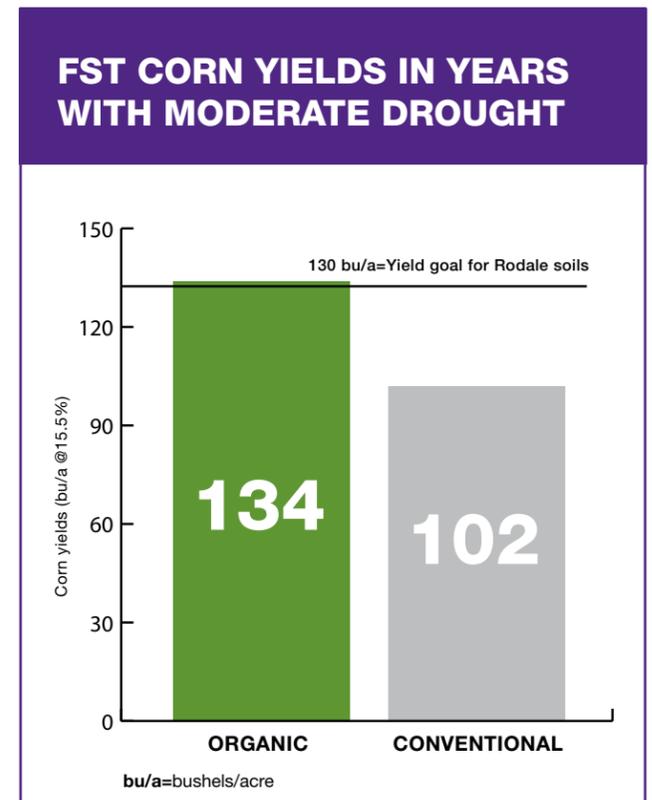
- **Over the 30 years of the trial, organic corn and soybean yields were equivalent to conventional yields in the tilled systems.**
- **Wheat yields were the same for organic and conventional systems.** (Wheat was only added to the conventional system in 2004).



Corn in the legume-based (left) and conventional (right) plots six weeks after planting during the 1995 drought. The conventional corn is showing signs of water stress.

- **Organic corn yields were 31% higher than conventional in years of drought.** These drought yields are remarkable when compared to genetically engineered “drought tolerant” varieties which saw increases of only 6.7% to 13.3% over conventional (non-drought resistant) varieties.

- **Corn and soybean crops in the organic systems tolerated much higher levels of weed competition than their conventional counterparts, while producing equivalent yields.** This is especially significant given the rise of herbicide-resistant weeds in conventional systems, and speaks to the increased health and productivity of the organic soil (supporting both weeds and crop yields).



GENETICALLY MODIFIED CROPS

According to the Department of Agriculture, 94% of all soybeans and 72% of all corn currently grown in the United States are genetically modified to be herbicide-tolerant or express pesticides within the crop. So, in 2008, genetically modified (GM) corn and soybeans were introduced to FST to better represent agriculture in America. GM varieties were incorporated into all the conventional plots.

We incorporated the GM crops to reflect current American agriculture, rather than to specifically study their performance. Our data only encompasses three years, but the research being done in the community at large highlights some of the clear weaknesses of GM crops:

- **Farmers who cultivated GM varieties earned less money** over a 14-year period than those who continued to grow non-GM crops according to a study from the University of Minnesota.
- **Traditional plant breeding and farming methods have increased yields of major grain crops three to four times more than GM varieties** despite huge investments of public and private dollars in biotech research.
- **There are 197 species of herbicide-resistant weeds, many of which can be linked directly back to GM crops,** and the list keeps growing.
- **GM crops have led to an explosion in herbicide-use** as resistant crops continue to emerge. In particular, the EPA approved a 20-fold increase in how much glyphosate (Roundup®) residue is allowed in our food in response to escalating concentrations.



Pesticides commonly used in agriculture have been found in drinking water, sometimes at levels above regulatory thresholds.

FEEDING THE WORLD

Agribusinesses have long clung to the rallying cry of needing to increase yields in order to feed the world. However, feeding the world is not simply a matter of yields.

The global food security community is shifting swiftly in support of an organic approach.

- **“Organic agriculture has the potential to secure a global food supply, just as conventional agriculture is today, but with reduced environmental impact.”** This is according to a report that came out of the Food and Agricultural Organizations of the United Nations (FAO) International Conference on Organic Agriculture and Food Security.
- **Agroecological farming methods could double global food production in just 10 years,** according to a report from the United Nations. Agroecological practices, like organic practices, attempt to mimic natural processes and rely on the biology of the soil and environment rather than synthetic sprays and other inputs.
- **Switching to organic methods in communities where people struggle to feed themselves and their families can lead to a harvest 180% larger than that produced by conventional methods.**

Numerous independent studies have shown that small scale, organic farming is the best option for feeding the world now and in the future. Not only does it produce competitive yields in a healthy and sustainable way as FST has shown, it also supports local communities and cultures. Therefore, our goal for the future is to continue to support the transition of conventional farms to organic farming systems.



ECONOMICS

Organic farmers have the potential to make more money with less land than conventional farmers. And the organic market is still growing. Organic food and beverage sales have grown from \$1 billion in 1990 to \$26.7 billion in 2010. And sales for organic fruits and vegetables in 2010 increased 11.8% over 2009, despite the slow economy.

Organic farming is also enriching communities and creating jobs. Research clearly shows the long-term economic viability of established organic systems for both farmers and the nation.

IN THE COMMUNITY

Rural American communities are in dire conditions because of the conventional agricultural trend of replacing labor with chemicals and machinery. Organic agriculture has the potential to turn that trend around:

- **Organic agriculture promotes job creation, providing for more than 30% more jobs per hectare than non-organic farms**, according to a report from the United Nations. The addition of on-farm processing and direct marketing, two practices fostered in organic systems, further increases the opportunities for job creation.
- **More of the money invested in an organic farm operation goes to paying people.**

ON THE FARM

When farmers talk yield, the understanding is that yield is directly correlated to profit—more bushels of product equals more money in the bank. The race to grow more crops on more acres is a result of this reality in the conventional agriculture industry. But this is certainly not the case across the board.

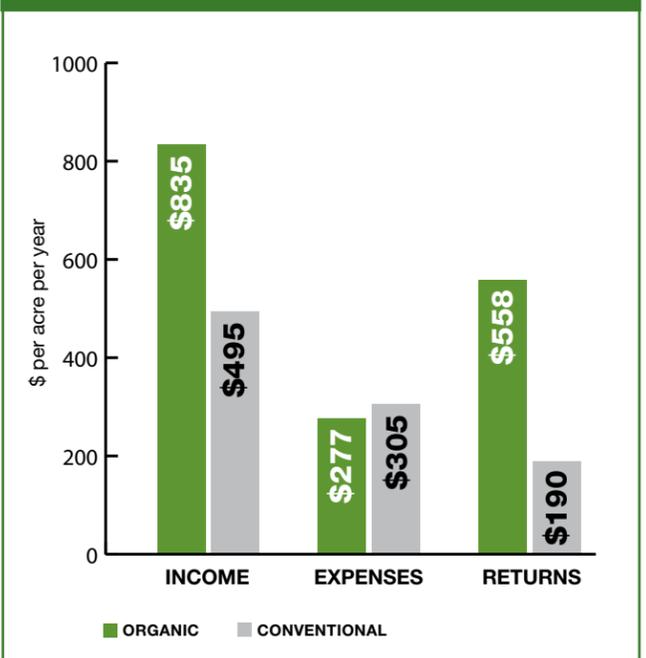
- **Organic farms are significantly more profitable.** According to the Organic Trade Association, organic farmers have an operating profit of \$45,697 compared to \$25,448 for conventional farmers.

- **Organic grain and soybean systems returned higher profits with organic premiums** a review of six Midwestern land-grant university studies found. Even without the premiums, half of the organic systems were still more profitable. The other half quickly made up the difference and surpassed the conventional systems when the price premiums were added.

FROM FST, we have found that:

- **The organic systems were nearly three times more profitable than the conventional systems.** The average net return for the organic systems was \$558/acre/year versus just \$190/acre/year for the conventional systems.
- **Even without a price premium, the organic systems are competitive with the conventional systems.** Marginally lower input costs make the organic systems economically competitive with the conventional system, even at conventional pricing.
- The most profitable grain crop was the organically grown wheat netting \$835/acre/year.
- No-till conventional corn was the least profitable crop netting just \$27/acre/year.

INCOME, EXPENSES & RETURNS IN FST ORGANIC AND CONVENTIONAL SYSTEMS



The economic analysis covers only the time period 2008-2010 to reflect data collected for the most recent cropping system comparisons.

ENERGY

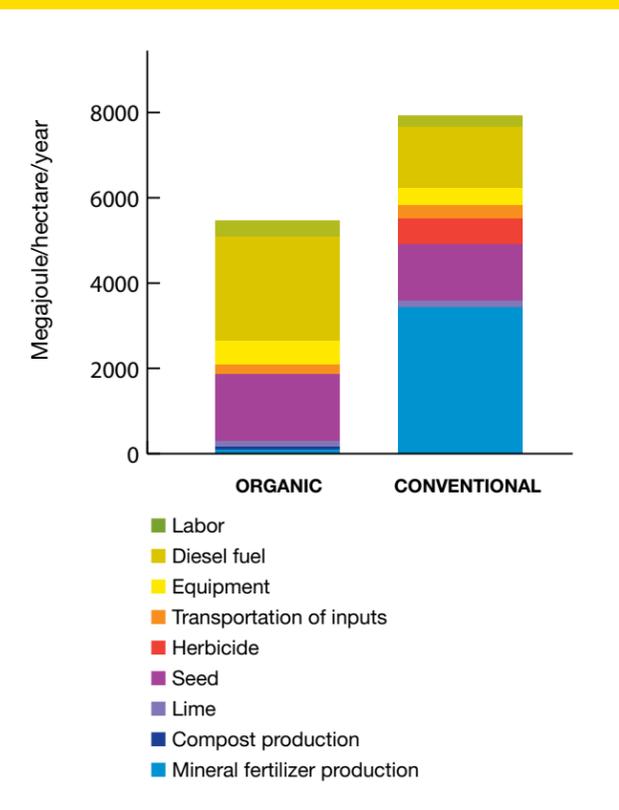
As the world's energy crisis continues, smart and efficient use of resources will become increasingly essential. Currently, conventional agriculture uses an enormous amount of oil to manufacture, transport and apply fertilizers and pesticides. All these processes release large amounts of greenhouse gases into the atmosphere. Figures from the Intergovernmental Panel on Climate Change (IPCC) say that agricultural land use contributes 12% of global greenhouse gas emissions.

INPUTS

Our data from FST shows that the organic systems use less energy and are more efficient than conventional systems:

- **The organic systems used 45% less energy than the conventional systems.**
- **Diesel fuel was the single greatest energy input in the organic systems.**
- **Nitrogen fertilizer was the single greatest energy input in the conventional systems representing 41% of the total energy.**
- **Production efficiency was 28% higher in the organic systems than in the conventional systems, with the conventional no-till system being the least efficient in terms of energy usage.**

ENERGY INPUTS



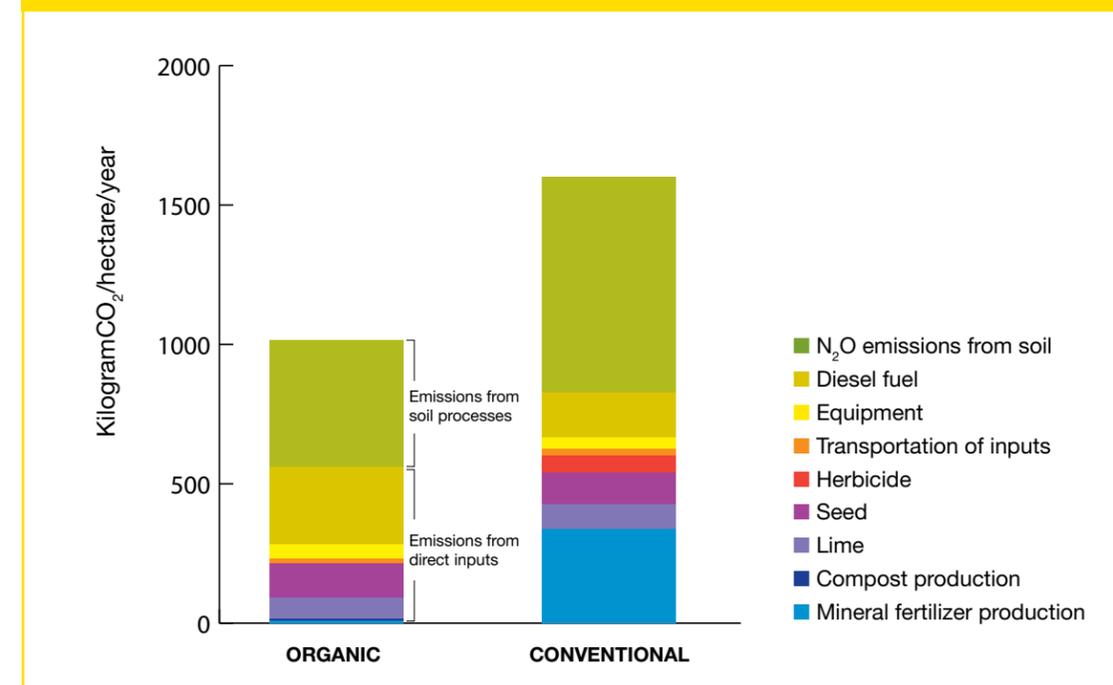
The energy analysis covers only the time period 2008-2010 to reflect data collected for the most recent cropping system comparisons.

EMISSIONS

When it comes to greenhouse gas emissions, the FST data shows conventional systems contribute much more to the atmosphere:

- **The conventional systems emit nearly 40% more greenhouse gases (GHG) per pound of crop produced than the organic systems.**
- **The biggest GHG emissions from direct inputs in the conventional system came from fertilizer production and on-farm fuel use.**
- **The biggest GHG emissions from direct inputs in the organic system came from fuel use and seeds.**

GREENHOUSE GAS EMISSIONS



(Note: In both organic and conventional systems, the highest overall GHG emissions were caused by soil processes fueled by nitrogen in mineral fertilizer, compost and crop residues).

HUMAN HEALTH

Conventional systems rely heavily on pesticides (herbicides, insecticides, fungicides, etc.) many of which are toxic to humans and animals. They are by name, definition, and purpose, designed to kill.

Numerous studies have begun to capture the true extent of how our low-level exposure to pesticides could be quietly causing serious health problems in our population. The toxins are nearly inescapable in the water we drink, the food we eat and the air we breathe.



- **Atrazine¹ exposure at time of conception has been linked to lower math and reading skills in children.**

- **Researchers measured organophosphates² in the urine of children and discovered levels of chemical indicators up to 14 parts per billion.** (All of which disappeared when they were put on an organic diet.)

- **Glyphosate³-based herbicides, currently legal in our food at low levels, have been shown to cause DNA damage, infertility, low sperm count, and prostrate or testicular cancer in rats.**

- **Pesticides (including ones that have been banned for years) have been found in breast milk and umbilical cord blood.**

- **Inactive ingredients in herbicide and pesticide brands have been found to be just as toxic, if not more so, than the active ingredients, and these ingredients aren't tested for human health impacts before being released.**

- **Some research has found certain agricultural chemicals can alter our DNA,** meaning the effects can be passed on through the generations.

- **More than 17,000 pesticide products for agricultural and non-agricultural use are currently on the market.** Exposure to these chemicals has been linked to brain/central nervous system disruption, breast, colon, lung, ovarian, pancreatic, kidney, testicular, and stomach and other cancers.

- **The EPA has required testing of less than 1% of the chemicals currently in commerce.**

When we've sampled for herbicide and nutrient leaching into groundwater in the FST, we've found:

- **Water leaching from the conventional system more frequently exceeded the legal limit of 10 parts per million for nitrate-nitrogen concentrations in drinking water compared to the organic systems.**

- **Atrazine leaching in the conventional system sometimes exceeded the maximum contaminate level set by the EPA for drinking water.** And concentrations in all conventional samples exceeded 0.1 parts per billion, a concentration that has been shown to produce deformities in frogs.

Intact soil core lysimeters are used to collect water from soil below the rooting zone of crops. A lysimeter resembles a large, underground, steel flowerpot with a hole in the bottom for collecting water – called leachate – that has drained away from the crop planted above it.



¹Atrazine is an active ingredient in herbicides. ²Organophosphates are the basis of many insecticides and herbicides, and are widely used as solvents and plasticizers. ³Glyphosate is the active ingredient in the herbicide Roundup®

WHAT'S THE BIG PICTURE?

Today we produce food within a system that is broken. Within roughly seventy years, our current chemical-based agricultural system is already showing its weaknesses—depleted soil, poisoned water, negative impacts on human and environmental health, and dysfunctional rural communities. We should be directing our valuable time and resources working towards a truly sustainable food production system based on sound biological principles.

To repair our food system, we must focus on the basics—soil health and water quality—and how we can improve upon these natural resources so that we return as much as we take, thus ensuring our future. By building and improving soil health, utilizing organic practices to fix nutrients in the soil, encouraging biodiversity, and greatly minimizing synthetic inputs, organic producers are ensuring the sustainability of the system indefinitely. Not just feeding the world's growing population today, or tomorrow, but far into the foreseeable future.

After thirty years of a rigorous side-by-side comparison, the Rodale Institute confidently concludes organic methods are improving the quality of our food, improving the health of our soils and water, and improving our nation's rural areas. Organic agriculture is creating more jobs, providing a livable income for farmers, and restoring America's confidence in our farming community and food system.

Since Rodale Institute first turned the soil in the Farming Systems Trial, we have inspired other long-term trials on organic agriculture in this country and beyond, from land-grant universities to international non-profits to research farms. The groundwork established in the FST is now being replicated and validated in the wider academic and agricultural community.

What do the next 30 years hold? We will continue to study the nuances of organic agriculture as they compare to those of the current chemical-reliant system. And we will continue to evaluate yield, economic viability, energy usage along the way as all these are indicators of a healthy, diverse and truly sustainable system. However, a change may be on the horizon. One which may see us exploring different crops or reaching beyond matters of yield and economics to consider nutrition and human health in more depth.

We have shown that organic can feed the world. Now it is time to take on the matter of feeding the world well.



REFERENCES

- Badgley, C., Moghtader, J., Quintero, E., Zakem, E., Chappell, M., Avilés-Vázquez, K., Samulon, A., and I. Perfecto. 2007. *Organic agriculture and the global food supply*. Renewable Agriculture and Food Systems, 22(2): 86-108.
- Cox, C., Hug, A., and N. Bruzelius. 2011. *Losing Ground*. Environmental Working Group. Web (www.ewg.org/losingground/report). August 17, 2011.
- De Schutter, O. 2010. *Report submitted by the Special Rapporteur on the right to food, Olivier De Schutter*. United Nations, General Assembly. Human Rights Council, Sixteenth session, Agenda item 3: Promotion and protection of all human rights, civil, political, economic, social and cultural rights, including the right to development. Web (www2.ohchr.org/english/issues/food/docs/A-HRC-16-49.pdf). August 17, 2011.
- Delate, K., Duffy, M., Chase, C., Holste, A., Friedrich, H., and N. Wantat. 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.
- El-Hage Scialabba, N. 2007. *Organic Agriculture and Food Safety*. Food and Agriculture Organization of the United Nations. Web (ftp://ftp.fao.org/paia/organicag/ofs/OFS-2007-5.pdf). August 17, 2011.
- Fernandez-Cornejo, J. 2011. *Agricultural Biotechnology: Adoption of Biotechnology and its Production Impacts*. USDA Economic Research Service. Web (www.ers.usda.gov/briefing/biotechnology/chapter1.htm). August 17, 2011.
- Finger, R., El-Benni, N., Kaphengst, T., Evans, C., Herbert, S., Lehmann, B., Morse, S., and N. Stupak. 2011. *A meta analysis on farm-level costs and benefits of GM crops*. Sustainability, 3(5): 743-762.
- Gasniera, C., Dumontb, C., Benachoura, N., Clair, E., Chagnonb, M., and G.E. Séralini. 2009. *Glyphosate-based herbicides are toxic and endocrine disruptors in human cell lines*. Toxicology, 262: 184-191.
- Gurian-Sherman, D. 2009. *Failure to Yield: Evaluating the Performance of Genetically Engineered Crops*. Union of Concerned Scientists. Web (www.ucsusa.org/assets/documents/food_and_agriculture/failure-to-yield.pdf). August 17, 2011.
- Heap, I. *The International Survey of Herbicide Resistant Weeds*. Web (www.weedscience.org). August 17, 2011.
- 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.
- 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(3): 146-154.
- Lu C., Toepel, K., Irish, R., Fenske, R.A., Barr, D.B., and R. Bravo. 2006. *Organic Diets Significantly Lower Children's Dietary Exposure to Organophosphorus Pesticides*. Environmental Health Perspectives, 114: 260-263.
- Mankame, T., Hokanson, R., Fudge, R., Chowdhary, R., and D. Busbee. 2006. *Alteration of gene expression in human cells treated with the agricultural chemical diazinon: possible interaction in fetal development*. Human & Experimental Toxicology, 25(5): 225-233.
- Pesticide Action Network, North America. *Pesticides 101: A Primer*. Web (www.panna.org/issues/pesticides-101-primer). August 17, 2011.
- 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.
- Reuben, S., Milliken, E.L., and L.J. Paradis. 2011. *America's Demographic and Cultural Transformation: Implications for Cancer*. National Cancer Institute, The President's Cancer Panel, 2009 – 2010 Annual Report.
- Richard, S., Moslemi, S., Sipahutar, H., Benachour, N., and G.E. Seralini. 2005. *Differential Effects of Glyphosate and Roundup on Human Placental Cells and Aromatase*. Environmental Health Perspectives, 113: 716-720.
- Ryan, M., Smith, R., Mortensen, D., Teasdale, J., Curran, W., Seidel, R., and D. Shumway. 2009. *Weed-Crop Competition Relationships Differ between Organic and Conventional Cropping Systems*. Weed Research 49, 572-580.
- Welsh, R. 1999. *The Economics of Organic Grain and Soybean Production in the Midwestern United States*. Henry A. Wallace Institute for Alternative Agriculture.
- Winchester, P. D., Huskins, J. and J. Ying. 2009. *Agrichemicals in surface water and birth defects in the United States*. Acta Paediatrica, 98: 664-669.
- 2007 Census of Agriculture, National Agricultural Statistics Service, USDA.
- 2011 Organic Industry Survey, Organic Trade Association.

HEALTHY SOIL, HEALTHY FOOD, HEALTHY PEOPLE, HEALTHY PLANET

RODALE INSTITUTE is a 501(c)(3) nonprofit dedicated to pioneering organic farming through research and outreach. Their landmark Farming Systems Trial® is the longest- running side-by-side comparison of organic and conventional agriculture. For over sixty years, the Institute has been researching the best practices of organic farming and sharing findings with farmers and scientists throughout the world, advocating for policies that support farmers, and educating consumers about how going organic is the healthiest option for people and the planet.



611 SIEGFRIEDALE ROAD, KUTZTOWN, PA 19530 TEL 610-683-1400 WWW.RODALEINSTITUTE.ORG

©2011 RODALE INSTITUTE (20589)

PRINTED BY *Nacci*
Printing, Inc.