The Renewable Deal

Plank 2**:** Adopt available sustainable, non-polluting, ecologically restorative, productive, profitable agricultural Best Available Management Practices and Best Available Technology nationwide.

Part 1: Organic Agriculture Systems: Undertake a national program to install organic farming cultural techniques to replace petrochemical-input farming.

Chapter 1: Organic Agriculture Productivity and Nutrition

--By Richard Lance Christie—

(Revised October 15, 2007)

Author's note: This is a preliminary draft and a work in progress. (Further explanation.)

Summary

Contemporary studies independently confirm that organic producers have equivalent crop yields to chemical input producers in temperate areas, and much higher crop yields in tropical areas. Numerous studies of U.S. organic farmers producing small grains, soybeans, and tomatoes show they realize yields equivalent to chemical input farmers. Studies show poor farmers in developing nations gaining huge increases in yield using organic agroecological farming techniques; that as farm size increases total productivity declines; and that organic farms are more capital and resource efficient than chemical input farms. Studies of both temperate and tropical farms consistently find that organically-managed farms are far more profitable per acre than their chemical input peers, or than the same farm was prior to its conversion to organic management.

Numerous studies find that organically grown crops are much higher in polyphenolic compounds which are potent antioxidants when consumed by humans, while having significantly less chemical residues than chemical-input agricultural crops. Organically-grown crops are likely to contain higher levels of the more complex carbohydrates, proteins, and enzymes which are associated with enhanced immune system function in both the plants and the animals that consume them. Organic soils capture and store carbon dioxide at much higher levels than chemically-farmed soils; if all corn and soybeans in the U.S. were grown organically, 580 billion pounds of additional carbon dioxide would be sequestered from the atmosphere (<**Error! Hyperlink reference not valid.**

Certified organic farming is not a quaint, romantic return to nineteenth century agricultural

techniques. All organic certification inspection schemes evaluate what the grower does to increase soil fertility, prevent pest and disease outbreaks, and enhance biodiversity in the farm environment. Vascular food crop plants co-evolved with the vast community of soil biota with which they are in symbiotic relationship. By restoring the soil biotic community to full diversity and function through organic management, the organic farmer equips food crops to perform at their genetic potential due to efficient nutrient cycling, pest and disease resistance support. Chemical input and organic growers of the same crop in temperate zones are likely to enjoy the same yields per hectare under ideal growing conditions, if the chemical input grower has employed organic soil fertility maintenance techniques such as green manure crops and/or crop rotation. However, adverse crop pressures such as drought, extraordinary heat or cold, flooding, and pest or disease epidemics will normally lower chemical- input agricultural yields per hectare more than organic farm yields. Meta-analysis of studies of farms in transition from chemical-input to organic agriculture find average yield decline during three-year transitional status is 18 percent, but by the fifth year from the beginning of transition to organic, yields have recovered to equal those achieved on that farm with chemical input agriculture.

Organic agriculture has many “external” benefits. *WorldWatch*, May/June 2006: “Studies have shown...that the ‘external’ costs of organic farming - erosion, chemical pollution to drinking water, death of birds and other wildlife - are just one-third those of conventional farming. Surveys from every continent show that organic farms support many more species of birds, wild plants, insects, and other wildlife than conventional farms. And tests by several governments have shown that organic foods carry just a tiny fraction of the pesticide residues of the nonorganic alternatives, while completely banning growth hormones, antibiotics, and many additives allowed in many conventional foods.”

World Agricultural Productivity If All Agriculture Was Organic
The University of Michigan School of Natural Resources Meta-Analysis

The University of Michigan School of Natural Resources reviewed 293 studies in the published agricultural literature which measured changes in agricultural crop productivity from chemical input through organic transition into mature organic production in temperature and tropical food crops.

The model for the current world food production system produced a yield of 2,786 calories per person per day, somewhat higher than the average caloric requirement for a healthy person of between 2,250 and 2,500 calories. This closely corresponds to the WorldWatch estimates of world agricultural production in their annual *Vital Signs* assessments done for the United Nations. A number of these calories of food produced do not reach consumers due to problems with the food distribution system and losses to pests, spoilage, and contamination. Increasingly, food crop calories are being diverted to biofuels production.

Substituting the meta-analysis mean for organic productivity in each crop in temperate and tropical agriculture from the studies of attained yield from organic farming, the University of Michigan model predicted the world agricultural system would produce 4,381 calories per person per day, a 70 percent increase in caloric production from the same farmed area worldwide.

A second, independent study led by Niels Halberg of the Danish Institute of Agricultural Sciences evaluated the potential of a global shift to organic farming utilizing a model developed by the World Bank's International Food Policy Research Institute. This model is considered the definitive algorithm for predicting food output, farm income, and the number of hungry people throughout the world. The study was done by economists, agronomists, and international development experts from across the European Economic Union. It arrived at the same conclusions as the University of Michigan School of Natural Resources study in respect to total caloric yield of an organic world agricultural production system. The model did not show an impact on world food prices from 100 percent organic conversion. Halberg's team concluded, "Modern non-certified organic farming is a potentially sustainable approach to agricultural development in areas with low yields due to poor access or inputs or low yield potential because it involves lower economic risk than comparative interventions based on purchased inputs and may increase farm level resilience against climactic fluctuations....Organic agriculture could be an important part of increased food security in sub-Saharan Africa."

The Michigan study contained what I consider to be an error in their estimates of North American and European organic farm crop yields, due to equal weighting of all studies regardless of vintage in the meta-analysis. If one does a time-series review of studies of temperate-climate organic yield, there is a clear trend as one goes from the past to the present: the more contemporary the study, the less organic yields in established organic farms are found to lag those in chemical input farms. This is a result of rapid progress in innovation of effective organic cultural techniques. The University of Michigan study did not adjust its estimates of yield in temperate climates to take this significant regression towards higher organic yields over the last two decades into account. The University of Michigan estimates of organic yield potential are therefore conservative and probably under-estimate organic corn yields by 6 percent, organic wheat yields by 3 percent, and organic soybean yields by 6 percent in the temperate growing areas of the northern and southern hemispheres.

The University of Michigan study evaluated the claims by such parties as Vaclav Smil and the U.S. Department of Agriculture (USDA) that enough nitrogen cannot be produced in a world organic agricultural system to support crop production at these needed yield levels. Smil claims in his book *Enriching the Earth: Fritz Haber, Carl Bosch, and the Transformation of World Food Production* that roughly two-thirds of the world food harvest depends on the Haber-Bosch synthesis process that produces ammonia fertilizer from fossil fuels. The USDA published a study finding that the total amount of animal manure available in the U.S. which is not already used as an agricultural fertility input would be capable of replacing only about one quarter of the Haber-Bosch synthetic ammonia fertilizer as a nitrogen input. These critics and others such as Norman Borlaug and John Emsley do not comprehend that most nitrogen production in organic systems is accomplished through natural on-farm nutrient cycles, e.g., combined crop and livestock systems; crop rotation utilizing leguminous cover crops which fix nitrogen; plowdown of "green manure" cover crops to compost in the soil - which studies show is eight times more effective per acre at building nitrogen and organic matter levels than plowing under eight inches of animal manure; and inoculation of healthy organic soils with *Azobacter*, *Azospirillum***,** and other free-living nitrogen-fixing bacteria.

The Michigan study reviewed 77 studies from temperate and tropical areas on nitrogen nutrient cycling in organic agriculture. They concluded that greater use of nitrogen-fixing crops in the world's major agricultural regions could result in 58 million tons more nitrogen being available to crops than the amount of synthetic nitrogen currently used each year. Examples of studies reviewed include:

- Rodale Institute in Pennsylvania used red clover as a winter cover crop in an oat/wheat-corn-soy rotation. Yields of oats, wheat, corn and soybeans were equivalent to chemical nitrogen fertilizer input control plots.
- In arid and semi-arid tropical regions like East Africa, where water is limited between periods of crop production, drought-resistant green manure crops like pigeon peas and groundnuts were effective at fixing nitrogen to support full crop yield levels.
- In Washington State, organic wheat growers match nitrogen-chemical-input wheat growers yields using winter field peas for nitrogen fixation in rotation with wheat crops.
- In Kenya, farmers using leguminous tree crops in the dry season have doubled or tripled their corn yields, as well as suppressing stubborn weeds and generating additional animal fodder.

In Kenya, farmers in "high potential areas" with above-average rainfall and rich soils got higher maize yields with chemical-input than organic agricultural techniques. However, organic farmers in areas with poorer natural resource endowments consistently outyielded conventional growers. In both the "high potential" and lower potential areas for maize yield, Kenyan organic farmers had higher net profits, return on capital, and return on labor.

United States Corn and Soybean Production

Cornell University professor David Pimentel analyzed 20 years' data from the Rodale Institute Farming Systems Trial. Published in the July, 2005, issue of *Bioscience*, Vol 55:7, Pimentel analyzed the environmental, energy, and economic costs and benefits of growing corn and soybeans organically versus using chemical input farming techniques. Pimentel's study compared a certified organic farm using legume-based, rotational systems to maintain soil fertility versus a farm that used recommended fertilizer and pesticide applications, and an organic farm that applied manure to maintain soil fertility. Neither the manure nor legume-based organic farms used chemical fertilizers or pesticides. For all three classes of farm, the research compared soil fungi activity, crop yields, energy efficiency, costs, and organic matter changes over time, nitrogen accumulation and nitrate leaching into surface and groundwater.

Pimentel found that the organic systems produced higher corn yields than chemical input systems over time, especially under drought conditions; in two drought years corn yields in the legume-based organic system were 22 percent higher than in the chemical input system. In a farm converting to organic, corn yields would drop about one third initially, but then recover to baseline by the end of four years and increase above chemical input baseline after that. Improving corn yield was associated with organic soil fertility management causing increases in organic content, moisture, microbial activity, and other soil quality indicators in the organic systems relative to the chemical input systems.

The soil carbon in the organic farm systems increased by 15 to 28 percent relative to the chemical input systems, which could have major implications for carbon sequestration to stop global warming. Soil nitrogen levels in both organic farming systems increased 8 to 15 percent relative to the chemical input system over time, but total nitrogen lost to nitrate leaching was the same for the organic and chemical input systems. This indicates more nitrogen was held in the organically-managed soils in a form accessible to the crops.

Pimentel concluded that organic farming can compete effectively with chemical input farming in growing corn, soybeans, wheat, barley and other grains. His study included a review of the current literature on organic and conventional agriculture comparisons. One likely error I detected in his study is his assertion that organic small grains producers have an average of 15 percent higher labor costs than chemical input producers. I believe he has confounded the higher costs of the organic conversion period with the labor costs associated with a mature organic system of production. In both my observation as an inspector and in some published studies, the cost of production including labor for mature organic systems is equal to or lower than that of chemical input producers in the same area and cropping system.

Researchers at the Iowa State University Neely-Kinyon Research Farm documented an 18 percent corn yield drag during the three-year transition from chemical-input to organic farming, but corn yield differences were insignificant after organic transition compared to pre-conversion yields. The research found organically-managed corn crop required 2.5 hours more labor per acre but was still more profitable per acre than chemical-input corn production.

Iowa State economist Mike Duffy studied profitability of commodity corn and soybean production in chemical-input farms <http://www.extension.iastate.edu/Publications/FM1712.pdf> while Craig Chase studied organic farm profitability in commodity corn, soybean, oat + alfalfa, and alfalfa production systems <http://www.extension.iastate.edu/Publications/FM1876.pdf>. Including government farm program payments, the chemical-input farmer enjoyed an average profit of $20 per acre. The average organic farmer enjoyed an average profit of $170 per acre. In concrete terms, if a farmer has a 600-arable-acre farm in corn or soybeans, if that farmer is certified organic he will make $102,000 a year from farming, putting him at about the 85th percentile nationally in annual income. If that same farmer is growing using chemical-input cultural techniques, he will earn $12,000 a year from farming. To earn as much as the organic farmer, he would have to farm 5,100 acres of corn or soybeans, or else he and/or his wife will have to have jobs off the farm to generate a decent annual income.

United Nations International Fund for Agricultural Development

In 2005, the Fund reported on organic agricultural production and economics in China and India. The report plotted cost of production, yield per acre, and selling price for organic agricultural products produced by farmers converting from chemical input to organic farming.

The report found organic farming is expanding rapidly in Asia because organic farmers can make more money. The value of organic exports from China, which has more than 1,000 certified organic farms and companies, grew from under $1 million in the mid-1990's to $142 million in 2003. In India, 2.5 million hectares were under organic production and 332 organic certifications were issued in 2004.
For the average small farmer converting from "conventional" to certified organic, yield per acre drops 30% in year one of conversion, rises to 20% of baseline in year two, 10% in year three, and returns to the same yield as before thereafter. Cost per acre for production rises 10% in year one, returns to baseline in years two and three, and declines to 10% below the cost of conventional production thereafter. Selling price remains flat the first two years of conversion because the crop is still not certified organic. In year three selling prices averages 20% higher than conventional because a number of crops have reached certified organic status 36 months from application of last prohibited input to the cropland. Year four and thereafter selling price averages 40% higher for small organic farmers in China and India than they were receiving for crops as chemical input farmers, with a 10% lower cost of production, with the same yield per acre as chemical input farming produces.

The 2005 study findings are consistent with an earlier 2001 study of six Latin American countries which found that farming organically yields better earnings and a higher standard of living for small farmers. The 2005 study examined yield, input cost, and sale price to determine the exact source of the better earnings.

The 2005 fund study found that organic agriculture is no panacea, but "can provide a long-term solution to poverty, while reducing migration and improving health conditions and the environment for entire communities."

Studies by the Indian Council on Agriculture provide context for these findings. The Council found that despite heavy pesticide use, pests are now causing damage to some 35 percent of crops, versus 5-10 percent damage rates before pesticides came into use. In addition, the number of pests damaging rice has increased consequent to pesticide use: from 40 species in 1920 to 299 species in 1992. I interpret this finding in light of experience with pesticide use in fruit orchards in the U.S., which suppressed predators, causing numerous pest species which had been held in check by the predators to multiply and cause damage; when the orchards convert to organic management, eight out of nine pest species effectively disappeared from the orchards in terms of causing any damage to tree vigor or the quality of the fruit crop.

The Indian Council studied farms in West Bengal and found that diversified farms that grew 55 different crops returned an income of 227,312 rupees per acre; a farm diversified into 14 crops returned an income of 94,596 rupees per acre; while a farm planted as a monoculture in one commodity crop produced an average income of 32,098 rupees per acre.

“The Real Green Revolution”

Nicolas Parrott at Cardiff University published a report of this title on 14 February 2002 at the Biofach 2002 conference in Nuremburg, Germany. He reported on the success and extent of organic and agroecological farming techniques being practiced in the developing world. His report analyzes the potential of new techniques and practices that work with the grain of nature, not against it, generating food security and good yields. The report was launched by German Agriculture and Environment Minister Renate Kunast together with the International Federation of Organic Agriculture Movements (IFOAM) and Greenpeace. In respect to crop yields, the report cited the following case studies:

> In Madhya Pradesh, India, average cotton yields on farms participating in the Maikaal Bio-Cotton Project are 20 percent higher than on neighboring conventional farms.
>
> In Madagascar, the SRI (System of Rice Intensification) has increased yields from the usual 2-3 tons per hectare to yields of 6, 8, or 10 tons per hectare.
>
> In Tigray, Ethiopia, the use of compost instead of chemical fertilizers has increased yields and the range of crops farmers can grow.
>
> In Brazil, the use of green manures and cover crops has increased yields of maize by between 20 and 250 percent.
>
> In the highlands of Bolivia, the use of bone meal and phosphate rock and intercropping with nitrogen-fixing Lupin species have significantly contributed to increases in potato yields.

The author concluded: “The Real Green Revolution shows how organic and agroecological farming can significantly increase yields for resource poor farmers, improve food security and sustain and enhance the environmental resources on which agriculture in the South depends.”

IFOAM said, “The...report elaborates on an aspect of the organic concept that is less known, i.e., the wide-spread implementation of organic and agroecological approaches in developing countries, not targeting a premium market, but local communities. The report demonstrates in a convincing way how well adapted organic agriculture is for making a real difference for the poor of the world.”

University of Essex, 200 Developing World Agricultural Projects Review

Researchers Jules Pretty and Rachel Hine looked at over 200 agricultural projects in the developing world that converted to organic and ecological approaches, and found that for all the projects yields increased an average of 93 percent. The database involved nearly 9 million farms on 30 million hectares.

Capital Efficiency and Farm Size

According to the 2002 U.S. Agricultural Census, the smallest category of farm with an average size of two hectares (4.94 acres), produced $15,104 per hectare gross with a profit of $2,902 per hectare. The largest category of farms, averaging 15,581 hectares (38,485 acres), yielded $249 per hectare with a profit of $52 per hectare.
A policy paper indicates concludes that a large body of evidence indicates that small farms are more productive than large ones in terms of total food produced per acre, by up to 1,000 times more output per unit of area. The productivity advantages of large-scale mechanized farms are based on measures of the yield of one crop per acre. A small, complex farm can produce far more food per unit of input cost (capital, labor). [Peter Rosset, "The Multiple Functions and Benefits of Small Farm Agriculture," Policy Brief No. 4, Institute for Food and Development Policy, September, 1999.]

In *Eat Here*, WorldWatch's Brian Halweil observes: "The inverse relationship between farm size and output can be attributed to the more efficient use of land, water, and other agricultural resources that small operations afford, including the efficiencies of intercropping various plants in the same field, planting multiple times during the year, targeting irrigation, and integrating crops and livestock. So in terms of converting inputs into outputs, society would be better off with small-scale farmers. And as population continues to grow in many nations and the amount of farmland and water available to each person continues to shrink, a small farm structure may become central to feeding the planet.

Organic Farming Research Foundation Literature Summary

In 2001, the Organic Farming Research Foundation's Bill Liebhardt summarized then-existing academic studies on organic yield in various crops:

> **Corn**: With 69 total cropping seasons comparing high input and organically grown crops, organic yields were 94% of the high chemical input corn production systems.
>
> **Soybeans**: Data from five states with 55 growing seasons of data showed organic yields 94% of high chemical input soybean production systems.
>
> **Wheat**: 16 crop year experiments found organic wheat producing 97% of the chemical input wheat yields.
>
> **Tomatoes**: At the University of California, 14 years of comparative research on tomatoes showed no yield differences between chemically-managed and organically grown crops. Studies show organic tomatoes have brix (solids) averaging 1-2 points above conventional tomatoes. Brix is a quality indicator in tomatoes.

"In summary, for a total of 154 growing seasons for different crops, grown in different parts of this country and both rain-fed and irrigated land, organic production yielded 95% of crops grown under conventional high-input conditions."

Other Organic Research Literature Summary
Productivity and Profitability

USDA Agricultural Research Service's economist David W. Archer and soil scientist Hillarius Kludze analyzed both economic risks and transition effects of switching to organic farming at the Swan Lake Research Farm near Morris, Minnesota. The 130-acre Swan lake farm is representative of corn-soybean farms in Minnesota. Archer and Kludze compared an organic corn-soybean rotation and an organic corn-soybean-spring wheat/alfalfa rotation, half grown with conventional and half with strip tillage techniques where only the middle of the seedbed is tilled. They found that when strip tillage is used in organic farming, a transition risk is an increase in weeds until farmers learn to manage the system. Computer simulations projected costs, yields and risks over a 20-year period, using yield and economic data from the four-year study and crop price records from recent years. These records showed that organic crops had fetched more than chemical-input crops: up to $14 more per bushel for soybeans, up to $3 per bushel more for corn, and up to $5 more per bushel for wheat. Lacking a historical record of organic alfalfa sales in Minnesota, the researchers assumed it would sell for the same amount as conventional. The computer model projected that farmers would net an average of $50 to $60 more per acre a year by going organic, even with the highest transition cost assumptions in the range used in the study. <http://www.ars.usda.gov/is/pr/2006/060725.htm?pf=1>

Alec McErlich, Director of Agricultural Research and Development for Small Planet Foods, reflects my experience exactly: "...it is the caliber of the grower which has the greatest impact on yield and quality....So often, university side-by-side comparisons are completed on ground where organic practices were utilized for just the period of the trial and often by staff with no or limited experience with organic principles."

Liebhardt then examines the yields achieved by real-world organic farmers in corn, soybeans, wheat, and tomato crops. Examples: average corn yield for Shelby County, Iowa were 130 bushels/acre; the organic farm did 131 Bu/ac. Soybean average for Shelby County was 45 Bu/acre, exactly what the organic farms yielded. Organic wheat growers in Kent County, Ohio, exactly matched the county average yield. Average yield per acre for tomatoes in California is 31 tons/acre; the organic growers get 30-36 tons/acre with a high of 42 tons/acre. Liebhardt refers to organic farming's improvement of soil quality as measured by soil structure, organic matter, biological activity, water infiltration and water-holding capacity supporting increased yields, particularly under drought conditions.

A 1987 article in *Nature* by Reganold, et al, concludes: "the organically-farmed soil had significantly higher organic matter content, thicker topsoil depth, higher polysaccharide content, lower modulus of rupture and less soil erosion than the conventional-farmed soil. This study showed that, in the long term, the organic farming system was more effective than the conventional farming system in reducing soil erosion, and therefore, in maintaining soil productivity."

A Colorado State University bulletin from the Program for Alternatives in Sustainable Agriculture, February, 1991, addresses "The Myth of Lower Yields." The article reports on an agronomic and economic survey of 20 alternative and conventional producers, dryland and irrigated, in Colorado, Kansas, and Nebraska. The study concluded, "Neither the alternative nor the conventional farmer group maintained consistently higher or lower yields. This clearly shows that high (or low) yields can be attained in either system and that alternative farming techniques are neither yield-enhancers nor yield-breakers. During the transition from conventional to alternative practices, considerable yield fluctuations may occur (but not always) as the new system becomes established." According to the study, the factor for success in farming, as measured by yields, is "good management." "Being attuned to the specific agroecosystem and having superb marketing abilities are identified as management skills that lead to farming success."

USDA Agricultural Research Service reported the results of a study comparing the degree of soil-building from organic versus no-till methods on the Henry A. Wallace Beltsville, Maryland research center. Plant physiologist John Teasdale, with the ARS Sustainable Agricultural Systems Laboratory, compared light-tillage organic corn, soybean and wheat with the same crops grown with no-till plus pesticides and synthetic fertilizers from 1994 to 2002. In a three year follow-up study, Teasdale grew corn with no-till practices on all plots to see which ones had the most productive soils. He found that the organic plots had more carbon and nitrogen and yielded 18 percent more corn than the former no-till chemical-input plots did. Teasdale concludes that organic farming's addition of organic matter in manure and cover crops more than offsets carbon, nutrient, and soil biotic losses from tillage for weed control. <http://www.ars.usda.gov/is/pr/2007/070710.htm>.

The Naysayers

Alex Avery of the Hudson Institute has delivered a number of screeds against organic agriculture. He supports genetically modified organisms in agriculture on the grounds that this is the only means to get the high yields necessary to feed a growing world population. He claims that organic agriculture produces only 55-60 percent of chemical input agriculture yields, and a decision to convert to organic agriculture in the world agriculture system is a decision to convert 18-20 million square miles of wild land habitat to agriculture to make up for diminished yields on existing croplands. He has also claimed that a shift to organic farming methods would result in an increase in pesticide use of hundreds of millions of pounds per year. He further claims that the pesticides used by organic farmers are far more persistent in and damaging to the environment than the pesticides used by chemical input farmers.

Nobel-Prize-winning plant breeder Norman Borlaug stated at a 2002 conference, "We aren't going to feed 6 billion people with organic fertilizer. If we tried to do it, we would level most of our forest and many of those lands would be productive for only a short period of time." Note the two major fallacies in Borlaug's reasoning also present in Avery's: (1) He assumes that organic agricultural yields on existing farmland would be very much lower than those achieved with chemical-input agriculture due to insufficient organic fertility input availability, and (2) He assumes that virtually all uncultivated wild areas on Earth would have to be converted to farmland to avert massive starvation. As detailed in the reviews above, neither assumption is valid.

Operating from the same false premises, Cambridge chemist John Emsley said, "The greatest catastrophe the human race could face this century is not global warming but a global conversion to 'organic farming' - an estimated 2 billion people would perish."

Following the money: Ten federal agencies, nine states, and Native American tribes are cooperating to reduce nitrogen and phosphorous run-off that ends up in the Mississippi and Gulf of Mexico, producing a huge "dead zone" of oxygen-depleted waters. The Hudson Institute's Center for Global Food Issues says, "There is no water quality crisis in the Gulf." Among the top contributors to the Hudson Institute are Monsanto, Dow, and Lilly, all huge agricultural chemical and pharmaceutical companies. The Environmental Protection Agency estimates that, to eliminate the dead zone in the Gulf of Mexico, nutrient flow into the Mississippi from agricultural chemical run-off must drop by 40 percent. The necessary reductions in chemical fertilizer applications to achieve this would cut into the profits of these agribusinesses that support Avery and his Institute. In short, the Hudson Institute is a junk science purveyor serving the interests of its corporate sponsors who are threatened by market loss due to customers converting to organic farming. Other organic critics innocently or deliberately echo this corporate-sponsored anti-organic propaganda.

Chapter 2: Why and How Organic Agriculture Works

Part 1: Natural Systems Enhancement/Restoration of Ecological Integrity

Plant and beneficial insect symbiosis: Plants and beneficial insects are linked in a complex symbiosis in which they co-evolved. Plants release many different volatile compounds into the air as their way of communicating with their surroundings. When a plant is attacked by a particular species of caterpillar, it releases a specific pheromone that lures the species of beneficial insect most likely to prey upon that species of caterpillar. The plant releases a slightly different pheromone depending on the pest species attacking it, thus sending a S.O.S. to the proper beneficials. The plant under attack also releases other compounds to inform neighboring plants know it is time to raise their defenses against the attacker.

In the organically-managed agricultural system, habitat for beneficials is deliberately enhanced. Soil biotic communities are intact and thus maintain the vascular plants in healthy condition with fully-functional immune systems, so that they are not susceptible to pest or disease attack. Consequently, the air around an organic crop is not often filled with distress signals from plants under attack, and when an attack occurs, there are likely to be beneficials nearby to respond to the pheromonal S.O.S. In contrast, in a chemical input agricultural environment, the pesticides used against pest insects have also killed off the beneficials. The crop vascular plants themselves are likely to be deficient in enzymes because of lack of micronutrients and organic compounds ordinarily provided to them by symbiotic soil biota which have been suppressed by direct chemical toxicity from agricultural chemicals and their residues. Such nutrient-deprived plants exhibit chemical signals which attract pest insects to attack them.

Sequestration of carbon in soils; soil organic content: Large amounts of carbon in inorganic forms absorb most visible wavelengths of light and give soils their characteristic dark brown shades. When carbon content is low, we see the red, yellow or gray hues of the underlying mineral soil.

Soils around the world hold 1,500 to 2,300 pentagrams (two quintillion grams) of carbon. That is two to three times the amount of carbon stored in the world's plant life at a given time.

After plants die, decomposers assimilate some of their carbon and respire the remainder as carbon dioxide. When the decomposers themselves die, their carbon can also be consumed and respired by other decomposers. The decomposers secrete enzymes which break down the tissue organic compounds into small molecules which the decomposers can then absorb as food. Decomposers cannot easily degrade all forms of soil carbon, however. For example, material from the cell walls of dead microbes reacts with other carbon compounds in the soil to form complex polymers. Many of these polymers are humic compounds which build up in soil because their chemical structures can withstand enzymatic attacks. Along with similar molecules called polyphenols, humic compounds can bind to and inactivate the decomposer's enzymes which would degrade them.

Other environmental factors diminish the efficiency of microbial enzymes. If soils are nitrogen-poor, microbe populations lack the building materials for DNA and RNA required for reproduction. The lesser number of microbes means a reduction in decomposing enzymes in the soil. In addition, some decomposing enzymes require oxygen as a substrate, so under anoxic conditions, such as a waterlogged peat bog, carboniferous plant materials accumulate undigested.

Part 2: Nutritional Content of Organically-Grown Crops

In the January/March 2006 issue of *The Food Magazine*, British nutritionist David Thomas reports that the mineral content of meat and milk products has declined significantly in the past 60 years. Analyzing food nutrient data from 1940 and 2002, Thomas found that the iron content in 15 different meat items fell on average 47%, though some products showed a decline as high as 80 percent. Thomas concludes that the transition to high-fat, high-calorie, and highly processed foods lacking in micronutrients has caused people to be simultaneously overfed and undernourished. A 2004 study from London Metropolitan University found that eating the same weight of chicken today versus 30 years ago yields twice as many calories but one-third to one-eighth the omega-3 fatty acids. Earlier U.K. and U.S. analyses found substantial nutritional losses in every food sub-group investigated. "Possible reasons for the nutrient declines include mineral depletion of the soil itself, changes in plant varieties, and loss of soil microorganisms." American researcher Donald R. Davis believes that large-scale industrial farming itself plays a key role through the application of yield-increasing synthetic fertilizers and irrigation water diluting micronutrient availability to plants from the soil.
McCance and Widdowson found the following changes in mineral composition of milk in milligrams from 1940 to 2002 in Britain:

	1940	2002	Change
Sodium	50	43	-14%

Potassium	160	155	-3%
Phosphorous	95	93	-2%
Magnesium	14	11	-21%
Calcium	120	118	-2%
Iron	0.08	0.03	-62%
Copper	0.02	<0.01	gone

What these researchers did not take into account is that synthetic fertilizers, pesticides and herbicides directly and indirectly suppress species of soil bacteria and fungi, some of which deliver mineral micronutrients to crop plants by chelating metal ions (embedding them within amino acid chains) so that they can be absorbed and metabolized by plants. If the chelating microorganisms are deficient in soil due to lack of nutrients or suppression by the toxic effects of chemical agricultural inputs, then existing chelated micronutrients will be exhausted by crops and the food crops will suffer from micronutrient deficiencies in formation of complex enzymes and polyphenols such as flavonoids, thus lowering the crop nutritional value relative to its caloric value from simple carbohydrates and proteins which the micronutrient-stressed plant can still form as long as it has sunlight, water, carbon, nitrogen, phosphorous, and potassium available to it.

In a 2003 issue of the *Journal of Agricultural and Food Chemistry*, a University of California - Davis team assessed the nutritional differences in marionberries (a type of blackberry), strawberries, and corn raised by three different methods:

- Organically - no pesticides, herbicides, or synthetic fertilizer inputs were used
- Sustainably - no pesticides or herbicides were used, by synthetic fertilizer was used
- Conventionally - pesticides, herbicides, and synthetic fertilizers were used

Crops grown organically or sustainable had much higher polyphenolic content than those grown "conventionally."

In 2002, British researchers evaluated 35 different brands of vegetable soup, both organic and non-organic. They found that on average, organic brands contained nearly six times as much salicylic acid, a natural anti-inflammatory agent. Earlier British research found that blood levels of salicylic acid rose in Ss eating salicylic-rich foods, and higher blood concentrations of the acid fight certain types of cancer as well as plaque build-up in the arteries.

University of California - Davis researchers studied kiwifruits grown organically versus with chemical pesticide, herbicide, and fertilizer inputs. The crops were grown at the same time, in the same soil type, under the same environmental conditions, and were harvested at the same stage of maturity from the same farm in Marysville, CA. Researchers assessed the physical characteristics of the fruit as well as compounds in the fruit associated with flavor and nutrition. Sugars and organic acids were the same in kiwifruits from both growing methods. The Es found: "All the main mineral constituents were more concentrated in organic kiwifruits, which also had higher levels of ascorbic acid and total phenol content, resulting in a higher antioxidant activity." [A Comparative Study of Composition and Postharvest Performance of Organically and Conventionally Grown Kiwifruits. *Journal of the Science of food Agriculture,* 3-27-07 online]

In a 15-month study of almost 2,000 subjects, those whose diet included the highest fruit intake had more than 70 percent reduced risk of heart attack and other cardiac problems compared with those who ate the least amount of fruit. On average, for each additional piece of fruit consumed each day, subjects showed a 10 percent reduction in coronary risk. Subjects who consumed vegetables three or more times each week had approximately 70 percent lower heart attack risk than those who ate no vegetables at all. These benefits of fruits and vegetables are attributed to flavonoids, which give fruits and vegetables their color. Flavonoids have both anti-inflammatory and antioxidant qualities which help curb chronic diseases: heart disease, lung cancer, stroke, asthma, and type 2 diabetes. Complex flavonoids are present in higher levels in fruits and vegetables which have the full array of bioavailable micronutrients available to them from organically-managed soils.

A new study published in mid-2007 on the Organic Center website examined 15 different red wines for polyphenolic compounds, resveratrol, antioxidant activity, and orthratozin A (OTA) contamination. Organic wines had the greatest concentrations of antioxidant activity and of the key antioxidant resveratrol, as well as the highest levels of polyphenols. The combination of farming practices used by organic farmers reduced the risk of mycotoxin formation, through a yet unidentified mechanism.

Endnotes

In this article, I refer to “certified organic agriculture” in order to make clear that I refer to the body of agricultural practices which would qualify the grower for organic certification under the International Federation of Organic Agricultural Movements (IFOAM) organic standards which are recognized as the international trade standard defining “organic” by the World Trade Organization. I do not mean to infer that an “organic grower” described here as such will actually seek or receive formal certification as an organic grower from an accredited certification body. Since ideas of what “organic” might mean vary greatly, I define “organic agriculture” as practices that are consistent with IFOAM organic standards. Looking into the future, I see world agriculture increasingly adopting organic cultural techniques as the cost-effectiveness of chemical inputs continues to decline. By 2050, I expect the world agricultural system to be de facto organic, with the bulk of practices and inputs used worldwide being those developed by certified organic farmers. However, a majority of the world’s farmers might still be using one or more techniques or inputs which would disqualify them from being certified as an organic producer under 2007 IFOAM organic standards. Agricultural consultant Don Lotter says that, “...if we do things right, we’ll build a lot of organic into conventional systems.” Lotter notes that the “integrated” approach often out-performs both a strictly organic and chemical-intensive approach in terms of yield, economics, and environmental benefits.

In this article, I do not use the term “conventional” to describe chemical input agriculture. There is nothing “conventional” about use of synthetic chemicals in agriculture when you view agricultural practices in the context of the history of agriculture. The use of synthetic pesticides in agriculture commenced after World War II when chemical companies looked about for some peacetime use for their capital investment in chemical warfare agent factories and discovered that chemical warfare nerve agents that worked to paralyze the nervous systems of humans and kill them would do the same to the nervous systems of insects. From the perspective of the history of human agriculture, the use of synthetic fertilizers and pesticides is a 50-year abnormality. The use of crop rotation, livestock and human manure as a fertility input, and what we have dubbed "integrated pest management" techniques is the millennial norm.

Organic certification standards have forced innovation in organics, and continue to do so. I have described certified organic agriculture as a game we are playing to force us to discover how we can produce enough food in the post-carbon future. Many seemingly intractable problems for which no organic control was effective, such as the codling moth in stone fruit, have been solved by organic innovators. In the case of the codling moth, the organic control technique developed has been evaluated to be twenty-five times more cost effective than pesticide spray control techniques in peaches by University of California studies.

Currently the bane of organic growers in the Intermountain West is control of stolon-based perennial weeds such as bindweed (wild morning glory) and Russian knapweed, which are propagated by mechanical cultivation. In affected agricultural areas, certified organic farmers who develop infestations of these noxious perennial weeds in a field will take the field out of organic production, spray it with Roundup Ultra or other herbicide effective against the weed, and after control is achieved rotate the field back into their organic farm program through a three-year transition. This is tolerated by organic certification agencies because of noxious weed control laws and want of any known "organic" control technique. Another problem in organics is maintaining soil fertility in perennial crops such as alfalfa where large quantities of biomass are removed from the field with each harvest, depleting the nutrients available to crop from the field nutrient cycle. In my inspection work throughout the Intermountain West, I am seeing innovative experimentation on bindweed control and fertility maintenance with some promising preliminary results. If innovation in organic agriculture continues at the same pace it has displayed from 1990 to the present, by the year 2050 we may well have a full "toolbox" of organically-certifiable cultural techniques and inputs which can deal with any agricultural fertility, pest, or disease problem more cost-effectively than any synthetic-chemical-based technique now utilized.

I am in favor of an agricultural future in which no synthetic chemicals are applied to crops or the soil because of the effects of these applications on soil biota. For every chemical fertilizer, pesticide, and herbicide, thus far studied to determine their impact on soil biota, an adverse effect has been found on some species either from the original chemical or from its metabolites in the soil. In short, applying synthetic chemicals appears to always compromise the ecological integrity of the soil biotic community. Since vascular food plants and the soil biotic community co-evolved, that chemically-unaltered natural dynamic represents the ecological system equilibrium point that best supports food crop growth and health, nutrient cycling, water retention and management in the water column, and control of pathogens. If you suppress various species of organisms in the soil through application of agricultural chemicals, you can safely assume you are damaging natural ecosystem support functions that benefit the crop and the continued vitality of the living soil community. It is not a good idea to do this, so I favor stopping.

My views of organic agriculture are shaped by my observations as an organic crop and livestock inspector of producers in Montana, Idaho, Wyoming, Utah, Colorado, New Mexico, and California since 1999. While inspecting, I have always gathered data on the quality, price, and yield not only of the crops grown by the organic applicant for certification, but by their non-organic neighbors. In small grain crops, the organic producers get between 10 percent and 500 percent more yield per acre than their chemical-input neighbors (for a wet versus an extreme drought year, respectively), and get price premiums for both being certified organic (typically about 20-50 percent premium) and for crop quality (typically about 10 percent) per bushel. Once a farmer is through transition and has achieved good soil tilth and mastery of the organic techniques that work for him or her on their land, total operational costs per acre of crop are usually lower than for chemical input farmers in the same crop in the same county. The combination of lower cost and higher revenue per acre makes certified organic operations far more profitable. In the Intermountain West, finding a given organic grower is 2,000 acres larger each year I inspect them, due to having acquired defunct chemical farmers' fields, is routine. Across crop systems west of the Rockies, I have determined that organic growers would be more profitable than their chemical-input peers if there were no market "organic premium" in the price they receive for the products they sell.

When you have a system which produces superior products at lower risk, for a higher profit, than its competitor, guess which system will take over the competitive field according to free market principles of economics?