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In this issue:

Promoting Sustainable Food Systems through Organic Agriculture: Past, Present and Future

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Introduction

According to the Organic Trade Association, U.S. sales of organic food and beverages have grown from $1 billion in 1990 to an estimated $20 billion in 2007, and are projected to reach nearly $23.6 billion in 2008. Organics represented approximately 2.8 % of overall food and beverage sales in 2006, and with sales growing 20.9 % in 2006, the organic food industry continues to be a fast growing sector (1).

Consumers purchase organic foods for a variety of reasons including a perceived reduced environmental impact and higher nutritive value (2). Research has partially supported consumers' beliefs surrounding organic foods (2,3,4). Two published reviews found lower levels of pesticide residues and nitrates and higher levels of vitamin C, polyphenols and certain minerals (e.g., iron, magnesium, and phosphorus) in organic crops (2,3). Research is being conducted to determine the mechanisms by which organic food and farming may promote human health (5,6).

One of the challenges surrounding organically produced foods is that the market price is often higher, which some argue is due to lower average yields than conventionally produced crops in some developed countries (2). However, more recent research has found that yields from U.S. organic farms can approximate yields from conventional agriculture (~ 90 %) for corn, soybean and winter wheat. These same researchers reported that crop yields were just as high, both in volume and in quality, for organic as for conventional alfalfa (7). And in developing countries, yields from organic agriculture have been found to surpass yields from conventional agriculture–without increasing the current land base (8,9). Thus, an alternative explanation for the market price differential between conventionally and organically produced foods is that many of the costs associated with conventional food production are "externalized," (10) that is, they are not factored into the final market price of a food product (e.g., environmental and public health costs associated with soil erosion and agricultural pesticide use) (11, 12, 13). In addition, the production of certain non-organic agricultural products, such as corn, soy, rice, wheat, cotton, and dairy products, is subsidized through Federal farm program payments, resulting in artificially low commodity prices (14).

The purpose of this article is twofold: 1) to describe the history of the organic agriculture movement in the U.S., including the development of a U.S. National Organic Action Plan and 2) to illustrate how organic agriculture can facilitate the development of more sustainable food systems through internalizing several of the externalized costs associated with intensive conventional agriculture, and, as a result, offers great potential to enhance human and environmental health.

History of the U.S. Organic Agriculture Movement

In the 1940's, Jerome I. Rodale applied Englishman Sir Albert Howard's "organic growing methods" on an experimental "organic" farm in Pennsylvania, and began publishing *Organic Farming and Gardening* magazine (which later was named *Organic Gardening*). Howard's methods, as applied by Rodale, were based on the concept that the soil consists of a complex, interactive ecosystem, reliant on the addition of organic matter from animal manures, cover crops, mulches, and other forms of natural materials. Rodale felt that post-war industrial agriculture–which was reliant on synthetic fertilizers and pesticides–depleted and contaminated the soil, and eliminated healthy organisms in the agricultural environment. As J.I. Rodale said in 1954, "Organics is not a fad. It has been a long-established practice–much more firmly grounded than the current chemical flair." (15). The Rodale Institute–located in Kutztown, Pennsylvania–remains influential in the modern organic agriculture movement.

In the U.S., the organic movement emerged from the ground up, with primary activity in the Northeast, Upper Midwest, and West Coast, during the late 1960's through the 1980's. Farmers and buyers (consumers) joined together to form various networks, such as buying clubs, farmers' markets, food cooperatives, marketing cooperatives, and farmer/buyer associations. These organizations established certification standards; organized organic conferences; held field days; and wrote publications, with little or no government or university support.

By the late 1980's, numerous non-government organizations and some states had established organic standards and certification systems. There were significant differences in the standards, which led the leaders of the organic movement to ask Congress to adopt the Organic

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Foods Production Act of 1990 (OFPA). The final rules to implement OFPA were published in December 2000, and went into full effect on October 21, 2002, establishing a consistent standard for organic food in the U.S. (16). See Table 1 for a list of organic agriculture definitions as well as the OFPA regulations and guidelines.

U.S. National Organic Action Plan

To support the growth and broaden the understanding of organic agriculture in the U.S., and to engage stakeholders in the organic movement, a U.S. National Organic Action Plan is being developed. The National Organic Action Plan project is led by the Rural Advancement Foundation, International (RAFI); the Organic Farming Research Foundation (OFRF); and the member organizations of the National Organic Coalition (NOC). This multi-year effort, modeled on similar action plans adopted throughout Europe, has engaged diverse participants in envisioning the future for organic food and agriculture in the U.S. and has outlined strategies for advancing and evaluating progress to realize that vision.

The goals of the National Organic Action Plan are to: articulate a shared vision, set objectives and benchmarks for measuring organic agriculture's social and environmental benefits, and formulate proposals for the growth of U.S. organic food and agriculture in the next decade and beyond. Just as important is to create a participatory, democratic process that engages the organic community in defining both policies at the federal, state/regional/local levels, as well as actions in the marketplace and in rural and urban communities (19).

Through a series of dialogues over five years, citizens from all sectors of the organic food chain – including consumers, farmers, farmworkers, retailers, processors, educators, and organic advocates - participated in creating a draft National Organic Action Plan (19). Participants who attended a National Summit meeting in La Crosse, Wisconsin, February 25-26, 2009, set priorities among the many proposals included in the draft, and the public at large has had the opportunity to offer comments. Public review and re-evaluation will continue into the future. For more on the National Organic Action Plan, go to: http://www.rafiusa.org/noap.html.

Potential Human and Environmental Health Benefits of Organic Agriculture

In the field of economics, agricultural externalities are defined as, "benefits or costs that are not included in the market price of goods and services" (20). As noted earlier, many of the costs associated with intensive conventional agriculture are not factored into the final market price of a product. For example, the U.S. public health costs of pesticide use are estimated at $1.1 billion dollars per year, based only on acute poisonings plus associated illnesses

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Table 1. Organic Agriculture Definitions, Regulations and Guidelines

Definitions of Organic Production and Agriculture:

In the U.S., the National Organic Program defines organic production as, "a production system that is managed in accordance with the Act [Organic Foods Production Act of 1990] and regulations in this part to respond to site-specific conditions by integrating cultural, biological, and mechanical practices that foster cycling of resources, promote ecological balance, and conserve biodiversity." (16)

The International Federation of Organic Agricultural Movements (IFOAM) defines organic agriculture as "a production system that sustains the health of soils, ecosystems and people. It relies on ecological processes, biodiversity and cycles adapted to local conditions, rather than the use of inputs with adverse effects. Organic agriculture combines tradition, innovation and science to benefit the shared environment and promote fair relationships and a good quality of life for all involved." (17)

The Food and Agriculture Organization of the United Nations (FAO)/ World Health Organization (WHO) Codex Alimentarius guidelines define organic agriculture as, "a holistic production management [whose] primary goal is to optimize the health and productivity of interdependent communities of soil, life, plants, animals and people." (8)

The Organic Foods Production Act Regulations and Guidelines

The Organic Foods Production Act of 1990 (USDA, National Organic Program), Section *6501 (purposes)* states that, "It is the purpose of this chapter: (1) to establish national standards governing the marketing of certain agricultural products as organically produced products; (2) to assure consumers that organically produced products meet a consistent standard; and (3) to facilitate interstate commerce in fresh and processed food that is organically produced." The Organic Foods Production Act of 1990 and the implementing National Organic Program regulation require, among other things, that all products labeled and sold as "organic" in the United States be produced on land that has been free of prohibited substances, including synthetic fertilizers, pesticides, and genetically engineered organisms, for at least three years prior to harvest of an organic crop. Livestock must be provided 100% organic feed and not given antibiotics or growth hormones. Processing facilities must be certified and take steps to protect organic products from being mixed with non-organic products or from being contaminated with pesticides, sanitizers, and other prohibited materials. A copy of the USDA National Organic Program regulation can be found at: www.ams.usda.gov/nop. (18)

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(12) and cancer (11). A more detailed review of the externalized costs associated with intensive conventional agriculture production practices is reported elsewhere (21-23). The potential human and environmental health benefits associated with large scale adoption of organic farming include: reduced exposure to agricultural pesticides; enhanced biodiversity and soil fertility; and reduced nitrogen pollution, energy use, and greenhouse gas emissions. Each of these areas is reviewed below in more detail.

Reduced Environmental Exposures to Agricultural Pesticides

Organic agriculture offers numerous opportunities to reduce environmental exposure to agricultural pesticides, which may be detrimental to human health. Some documented human health risks associated with environmental exposure to pesticides include childhood cancer (24, 25), solid tumors (24), autism spectrum disorders (26), birth defects (27), spontaneous abortion (28), negative reproductive development in sons with mothers exposed to pesticides (e.g., reduced testosterone concentrations and sexual organ growth) (29), poor semen quality and reduced male fertility (30), diabetes (31), insulin resistance (32), and increased body mass index (33, 34).

A recent systematic review on pesticides and childhood cancer (24), found that, "[a] number of epidemiological studies consistently reported increased risks between pesticide exposures and childhood leukemia, brain cancer, neuroblastoma, non-Hodgkin's lymphoma, Wilms' tumor, and Ewing's sarcoma. An extensive review of these studies was published in 1998…. Fifteen case-control studies, 4 cohort studies, and 2 ecological studies have been published since this review, and 15 of these 21 studies reported statistically significant increased risks between either childhood pesticide exposure or parental occupational exposure and childhood cancer. Therefore, one can confidently state that there is at least some association between pesticide exposure and childhood cancer." Additional research is needed to assess gene-environment interactions and improve exposure measures (24).

Several studies have shown that there is a large range of vulnerability to exposure to organophosphate (OP) pesticides, especially in infants, due to genetic variability in a key enzyme – PON1 (paranoxonase 1/arylesterase), which breaks down these pesticides in the body. For example, one study involving 130 Latina mothers and their children in the Salinas Valley region of California found that newborn children can be 65 to 164 times more sensitive than adults to the OP pesticides, diazinon and chlorpyrifos (Lorsban) (35). The Food Quality Protection Act (FQPA) of 1996 requires the Environmental Protection Agency (EPA) to use an additional 10-fold safety factor in its risk assessment when setting pesticide tolerances for infants, children and other subpopulations that may have special sensitivities (when data show that they may be more sensitive or if key data are not available). However, based on the documented large range of vulnerability to OP pesticide exposures (35), some scientists have expressed concern that the FQPA's 10-fold safety factor may not adequately protect high-risk groups, especially pregnant women and infants, from exposures to certain OP pesticides (36).

The adequacy of the EPA's pesticide tolerances is a contentious issue – with points of disagreement between some agency scientists and administrators (36). One of the points of contention is whether or not the EPA's pesticide testing process includes sufficient evaluation of behavior, learning or memory in developing animals. There is evidence that low-level exposure to OP pesticides could be linked to neonatal neurotoxicity. Additional studies are being conducted to assess the potential health consequences of these low-level OP pesticide exposures to older children (36).

Based on animal data, some researchers also believe that fetal and/or neonatal low-dose exposure to certain OP pesticides (e.g., chlorpyrifos and parathion) may play a role in the increased incidence of obesity and diabetes through their disruption of glucose and fat homeostasis (37, 38). Similarly, other scientists have argued that certain endocrine disrupting chemicals, including tributyltin, (a fungicide) could lead to inappropriate lipid metabolism and increased body fat mass (39, 40). Such endocrine disrupting chemicals (including tributyltin) have been termed "obesogens" (40). Endocrine disrupting chemicals are compounds that mimic or interfere with the normal actions of endocrine hormones including estrogens, androgens, thyroid, hypothalamic and pituitary hormones (39).

Recent findings from Lu and colleagues (41) demonstrated that dietary intake represents the major source of exposure to OP pesticides in young children. In a longitudinal study of urban/suburban children in the greater Seattle, Washington area, these researchers found that by substituting organic fresh fruits and vegetables for corresponding conventional items, the median urinary metabolite concentrations for malathion and chlorpyrifos (OP pesticides) were reduced to non-detectable or nearly non-detectable levels. They also noted a seasonal difference in OP metabolite concentrations.

Thus, these authors hypothesized that higher levels of consumption of imported produce during the winter and spring seasons may have led to higher OP exposures. Evidence in support of this theory is contained in a report prepared by the EPA Office of the Inspector General, which showed a significant shift in residues and risk from domestically grown fruits and vegetables to imports since the passage of the FQPA (42). Previous research by these same investigators found that organic diets significantly lowered children's dietary exposure to OP pesticides (43).

Recent analyses have found that organic samples contain fewer pesticide residues than conventional samples. For example, from 1993-2004, 66 % of the conventional food samples tested by the USDA's Pesticide Data Program had one or more pesticide residues and 17% of the organic samples contained residues. Similar results were obtained for 2004. Seventy-eight percent of conventional samples had residues while 16 % of the organic samples tested positive for pesticide residues (44). Despites rules that prohibit organic farmers from applying synthetic chemicals to organic crops, about 15-20 % of organic fruits and vegetables tested by the Pesticide Data Program in recent years are found to contain residues of prohibited synthetic pesticides. This is because pesticides are often present and mobile across agricultural lands (e.g., pesticide drift, dust blowing from one field to another). Another cause is cross-contamination of tainted irrigation water. In addition, some insecticides persist in the soil, even after conversion to organic management. Finally, post-harvest contamination sometimes occurs in storage facilities (44).

A more recent analysis of up-to-date pesticide residue data based on USDA's Pesticide Data Program by the Organic Center found significantly greater pesticide risk linked to consumption of imported conventionally-produced fruits and vegetables as compared to domestic conventionally-produced fruits and vegetables (45). The dietary pesticide risk measure – or dietary risk index (DRI) - was calculated as the ratio of the mean residue level and the pesticide's chronic Reference Concentration (cRfC). A pesticide's cRfC is determined by its toxicity as estimated by the EPA. This calculation is based on three pieces of information: 1) the serving size of a given food (usually in grams); 2) the weight of a child (usually in kilograms); and 3) and the chronic toxicity of the pesticides, as determined by the EPA ("acceptable intakes" are expressed as milligrams of the pesticide per kilogram of body weight per day). Fruit and vegetable products were the focus of this analysis because they account for such a large share of the total dietary risk. Furthermore, the fruits and vegetables in this analysis focused on foods that are important in the diets of infants and children. Finally, the DRI values calculated within this analysis are only applicable to fruits and vegetables tested within the USDA's Pesticide Data Program (45).

Based on this analysis, it was concluded that multiple dietary pesticide residues are eight times more likely to be present in conventional than in organic produce (45). The analysis also concluded that converting the nation's eight million acres of produce farms to organic-coupled with buying imported organic produce, would reduce risks associated with exposure to pesticides by 97 % (45). Imported conventional fruits that posed the greatest pesticide risk included: grapes, nectarines, peaches, pears, strawberries, cherries, and cantaloupe. Imported conventional vegetables that posed the greatest pesticide risk included: sweet bell peppers, lettuce, cucumbers, celery, tomatoes, green beans, and broccoli. Domestically-grown conventional fruits that posed the greatest risk included: cranberries, nectarines, peaches, strawberries, pears, apples, and cherries. Domestically-grown conventional vegetables that posed the greatest pesticide risk included: green beans, sweet bell peppers, celery, cucumbers, potatoes, tomatoes, and peas (45). The Organic Center's pocket guide for reducing dietary pesticide exposure is

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available for download at: http://www.organic-center.org.

Enhanced Biodiversity and Soil Fertility

While results vary among taxonomic groups (46), most research has shown that biodiversity is enhanced on organic compared to conventional farms (47, 48). For example, in a landmark 21-year study, researchers reported higher levels of soil fertility and higher biodiversity in organic plots (compared to non-organic systems) whereas pesticide inputs decreased by 97 % in the organic systems (49). Oehl et al (50) found a greater diversity of soil microorganisms on organic farms than on conventional farms. Scientists in New Zealand found that organic management of apple orchards improved soil physical properties and the diversity of soil microbial populations (51). Thus, in summary, organic agriculture has the potential to restore biodiversity and associated ecosystem services (e.g., regeneration of soil fertility). In contrast, agricultural intensification, including agricultural pesticide use, has resulted in biodiversity losses worldwide (52). The importance of agricultural biodiversity in enhancing dietary diversity and global food security (53), and biodiversity's crucial role in modern medicine (for example, drugs such as aspirin and lovastatin are derived from nature) has been described elsewhere (54).

Another benefit of organic farming systems is improved soil quality. When comparing organic and conventional farming systems, researchers found that levels of soil organic matter were higher in organic systems. For example, manure- and legume-based organic farming systems from nine long-term experiments in the U.S. were found to increase soil organic carbon and total nitrogen compared with conventional systems (55). In addition, organic systems have reduced soil erosion because of the use of crop rotation and cover cropping (56). Large amounts of organic matter returned to the soil in organic farming systems encourage healthier, more robust roots, higher levels of available micronutrients, water infiltration and retention and below-ground microbial activity that can help increase crop nutrient density (57). Soils with less organic matter allow more surface runoff (removing topsoil and nutrients with water); permit higher surface evaporation; and retain less water within the soil structure (23, 58, 59). In one study that evaluated the performance of no-tillage versus organic cropping systems, researchers found that after nine years, organic cropping systems (for grain production) resulted in higher soil carbon and nitrogen concentrations at all depths at 30 centimeters (12 inches) than other agricultural cropping systems, including no-tillage systems. Based on these results, the authors concluded that organic cropping systems may provide more long-term soil benefits than conventional no-tillage cropping systems despite the use of tillage in organic cropping systems (60).

Despite the soil building benefits of organic cropping systems, some research has noted that the soil-building benefits of organic farming may not be achieved because of difficulty controlling weeds (61). However, the U.S. National Organic Program Final Rule, section 205.205, requires organic farmers to implement soil-building crop rotations, which include sod, cover crops, green manures, and catch crops, to improve soil quality; break weed, pest and disease cycles; manage nutrients; and prevent erosion (16). Diversified organic systems with perennial hay crops included in the rotation could maintain a lower weed seedbank and lower weed abundance than simpler grain crop rotations (62). Using rotations with perennial crops could benefit organic farming systems by reducing weed populations and eliminating the need for tillage during a significant part of the rotation. Advances in equipment design have also led to improved control of annual weeds by rolling cover crops to form a dense, tight mat of residue in no-tillage organic systems (61). More research is needed in this area.

Reduced Nitrogen Pollution, Energy Use and Greenhouse Gas Emissions

The intensification of agricultural production over the past 60 years and subsequent increase in nitrogen inputs have resulted in substantial nitrogen pollution and ecological damage. The primary source of nitrogen pollution is from nitrogen-based synthetic fertilizers. Nitrogen compounds from fertilizers can enter the atmosphere as nitrous oxide (N_20), and contribute to global warming (63). Nitrous oxide (N_20) is one of the three major greenhouse gases and the primary source is synthetic nitrogen fertilizer (64). The application of synthetic nitrogen fertilizers can also result in nitrogen leakage from agricultural systems into groundwater, rivers, and coastal waters (65), resulting in eutrophication (the accumulation of dissolved nutrients in a body of water that can lead to algae blooms, low dissolved oxygen, and lower water quality). Inorganic nitrogen pollution of ground and surface waters can result in adverse effects on human and environmental health as well as adverse effects on the economy (66).

A study published in the *Proceedings of the National Academy of Sciences* reported that use of organic versus synthetic fertilizers can play a role in reducing the adverse effects of nitrogen-based fertilizers (63). More specifically, these researchers found that nitrogen losses to groundwater and the atmosphere were reduced in organic orchards, relative to conventional orchards. Annual nitrate leaching was 4.4-5.6 times higher in conventional plots than in organic plots. In addition, the organically farmed soils exhibited higher potential denitrification[1] rates, greater denitrification efficiency, higher levels of organic matter, and greater microbial activity than the conventionally farmed soils (63). Furthermore, researchers at the University of Minnesota have found that alternative cropping systems, including organic, reduced the amount of water lost in drainage tiles by 41 % compared to a conventional corn-soybean rotation, and reduced nitrate-nitrogen losses by 60 % (67).

Conventional agricultural production utilizes more overall energy than organic systems due to its heavy reliance on energy intensive synthetic fertilizers, synthetic pesticides and concentrated feed, which organic farmers forego (68). Rising fuel and food prices highlight the importance of making agriculture less energy- and external-input dependent. The manufacturing of synthetic pesticides and fertilizers is dependent upon oil and natural gas, respectively (23).

A large proportion of the climate change mitigation potential of agriculture arises from soil carbon sequestration. Techniques to increase soil carbon storage, including no-tillage and reduced-tillage farming, cover crops, water conservation, and improved crop and grazing land management are those used in organic farming systems (69). Rodale Institute's Farming System Trial (FST), the longest-running side-by-side comparison of organic and conventional farming systems in the U.S. and one of the oldest trials in the world, has documented the benefits of an integrated systems approach to farming that uses regenerative, organic practices that include cover crops, composting, and crop rotations to reduce atmospheric carbon dioxide (CO_2) – by pulling it from the air and storing it in the soil as carbon. Organically managed soils can convert carbon from a greenhouse gas into a food-producing asset. Soils that are rich in carbon conserve water, and support healthier plants that are more resistant to drought, stress, pests

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[1] Denitrification reduces nitrates to nitrogen gas (N2), thus replenishing the atmosphere. In most unmanaged systems, the majority of the gas produced during denitrification is fully reduced N2, a non-reactive and environmentally benign gas (63, 65).

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and diseases. And even though climate and soil type affect sequestration capacities, multiple research efforts have illustrated that regenerative agriculture, if practiced on the planet's 3.5 billion tillable acres, could sequester up to 40 % of current CO_2 emissions (70).

Researchers are still in the process of determining the mechanisms by which soil carbon sequestration takes place. However, one of the most significant findings is the high correlation between increased soil carbon levels and very high amounts of mycorrhizal fungi, which help slow down the decay of organic matter (23). Beginning with the Rodale Institute's FST, collaborative studies by the USDA's Agriculture Research Service (ARS) have shown that the biological support system of mycorrhizal fungi are more prevalent and more diverse in organically managed systems than in soils that depend on synthetic fertilizers and pesticides. These fungi work to conserve organic matter by aggregating organic matter with clay and minerals. In soil aggregates, carbon is more resistant to degradation than in the free form and more likely to be conserved (70).

Although most attention has focused on CO_2, it has been noted that other greenhouse gases, including methane (CH_4) and nitrous oxide (N_20), have greater global warming potentials than $C0_2$, of which the animal agriculture sector is a primary contributor (22). As noted previously, nitrogen compounds from synthetic nitrogen fertilizers can enter the atmosphere as nitrous oxide (N_20), and contribute to global warming (e.g., synthetic fertilizer is used in conventional corn production) (64). A recent study by researchers in Canada found that a transition to organic crop production (for canola, corn, soy and wheat), would consume, on average, 39 % as much energy and generate 77 % of the global warming emissions associated with current national production of these crops. The authors noted that "[t]hese differences were almost exclusively due to the differences in fertilizers used in conventional and organic farming, and were most strongly influenced by the higher cumulative energy demand and emissions associated with producing conventional [synthetic] nitrogen fertilizers compared to the green manure production used for biological nitrogen fixation in organic agriculture." (71)

Conclusion

Organic agriculture continues to be a fast growing sector in the U.S. and abroad. The recent development of a U.S. National Organic Action Plan, which is modeled after similar action plans developed in Europe, highlights the ongoing interest in organic agriculture among a wide range of U.S. stakeholders including: consumers, farmers, farmworkers, retailers, processors, educators, and organic advocates. A more widespread adoption of organic agriculture can facilitate the development of more sustainable food systems through internalizing several of the externalized costs associated with intensive conventional agriculture, and, as a result, offers great potential to enhance human and environmental health. A comprehensive list of internet-based resources where food and nutrition professionals can find more information on organic food and farming is available on the Hunger and Environmental Nutrition (HEN) dietetic practice group website.

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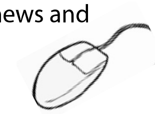

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