Ecological Impacts of Industrial Agriculture and the Possibilities for Truly Sustainable Farming

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Until about four decades ago, crop yields in agricultural systems depended mainly on internal resources, recycling of organic matter, built-in biological control mechanisms, and natural rainfall patterns. Agricultural yields were modest but stable. Production was safeguarded by growing more than one crop or variety in a field as insurance against pest outbreaks or severe weather. Inputs of nitrogen were gained by rotating major field crops with legumes. Growing many different types of crops over the years in the same field also suppressed insects, weeds, and diseases by effectively breaking the life cycles of these pests. A typical corn-belt farmer grew corn rotated with several crops including soybeans as well as the clovers, alfalfa, and small grains needed to maintain livestock. Most of the labor was done by the family with occasional hired help, and no specialized equipment or services were purchased from off-farm sources. In these types of farming systems the link between agriculture and ecology was quite strong and signs of environmental degradation were seldom evident.

The significance of biological diversity in maintaining such systems cannot be overemphasized. Diversity of crops above ground as well as diversity of soil life below ground provided protection against the vagaries of weather, market swings, as well as outbreaks of diseases or insect pests. But as agricultural modernization progressed, the ecology-farming linkage was often broken as ecological principles were ignored or overridden. Numerous agricultural scientists agree that modern agriculture confronts an environmental crisis. A growing number of people have become concerned about the long-term sustainability of existing food production systems. Evidence has accumulated, showing that, while the present farming systems have been extremely productive and able to finish low-cost food, they also bring a variety of economic, environmental and social problems.

Evidence also shows that the very nature of the agricultural structure and prevailing policies in a capitalist setting have led to this environmental crisis by favoring large farm size, specialized production, crop monocultures, and mechanization. Today as more and more farmers are integrated into international economies, the biological imperative of diversity disappears due to the use of many kinds of pesticides and synthetic fertilizers, and specialized farms are rewarded by economies of scale. In turn, lack of good rotations and diversification take away key self-regulating mechanisms, turning monocultures into highly vulnerable agricultural ecosystems (agroecosystems) dependent on high chemical inputs.

The Expansion of Farm Specialization and Monocultures

Monocultures or near monocultures have increased dramatically worldwide, where the same crop (usually corn, wheat, or rice) is grown year after year in the same field, or very simple rotations are used (such as corn-soybeans-corn-soybeans). Also fields that in the past contained many different crops, or a single crop with a high degree of genetic variability, are now entirely devoted to a genetically uniform single crop. Available data indicate that the amount of crop diversity per unit of arable land has decreased and that croplands have also shown a tendency toward concentration in fewer hands. There are political and economic forces influencing the
trend to devote large areas to monoculture, and in fact the economies of scale of such systems contribute significantly to the ability of national agricultures to serve international markets.

The technologies allowing the shift toward specialization and monoculture were mechanization, the improvement of crop varieties, and the development of agrochemicals to fertilize crops and control weeds, insects, and other crop pests as well as antibiotics and growth stimulants for agricultural animals. United States government commodity policies over the last several decades encouraged the acceptance and utilization of these technologies. In addition, the largest agribusiness corporations have found that concentrating certain processing facilities for a given product (chickens, hogs, or wheat) in specific areas of the country produces more profits, which lead to more farm and regional specialization. As a result, farms today are fewer, larger, more specialized, and more capital intensive.

There are many problems associated with the increasing extent of monoculture, including the simplification of cropping systems devoted to a single crop variety to the simplification of the landscape through the elimination of natural vegetation

The First Wave of Environmental Problems

The specialization of farms has lead to the image that agriculture is a modern miracle of food production. However, excessive reliance on farm specialization (including crop monocultures) and inputs such as capital-intensive technology, pesticides, and synthetic fertilizers, has negatively impacted the environment and rural society. A number of what might be called Aecological diseases@ have been associated with the intensification of food production and can be grouped into two categories. There are problems directly associated with the basic resources of soil and water, which include soil erosion, loss of inherent soil productivity and depletion of nutrient reserves, salinization and alkalinization (especially in arid and semi-arid regions), pollution of surface and ground water, and loss of croplands to urban development. Problems directly related to crops, animals and pests include loss of crop, wild plant, and animal genetic resources, elimination of natural enemies of pests, pest resurgence and genetic resistance to pesticides, chemical contamination, and destruction of natural control mechanisms. Each Aecological disease@ is usually viewed as an independent problem, rather than what it really is---a symptom of a poorly designed and poorly functioning system. Under conditions of intensive management, treatment of such Adiseases@ requires an increase in the external costs to the extent that, in some agricultural systems, the amount of energy invested to produce a desired yield surpasses the energy harvested.

The substantial yield losses due to pests, about 20 to 30 percent for most crops despite the increase in the use of pesticides (about 4.7 billion pounds of pesticides were used worldwide in 1995, 1.2 billion pounds in the U.S. alone) is a symptom of the environmental crisis affecting agriculture. Cultivated plants grown in genetically homogeneous monocultures do not possess the necessary ecological defense mechanisms to tolerate the impact of pest outbreaks. Modern agriculturists have selected crops mainly for high yields and high palatability, making them more susceptible to pests by sacrificing natural resistance for productivity. And as modern agricultural practices reduce or eliminate the resources and opportunities for natural enemies of pests, their numbers decline, decreasing the biological suppression of pests. Due to this lack of natural controls, an investment of about $40 billion in pesticide control is incurred yearly by U.S. farmers, which is estimated to save approximately $16 billion in U.S. crops. However, the indirect
costs of pesticide use to the environment and public health have to be balanced against these benefits. Based on the available data, the environmental cost (impacts on wildlife, pollinators, natural enemies, fisheries, water, and development or resistance) and social costs (human poisonings and illnesses) of pesticide use reach about $8 billion each year. What is worrisome is that pesticide use is still high and still rising in some cropping systems. Data from California show that from 1991 to 1995 pesticide use increased from 161 to 212 million pounds of active ingredient. This increase was not due to increases in planted acreage, as statewide crop acreage remained constant during this period. Much of the increase is for particularly toxic pesticides, many of which are linked to cancer, used on such crops as strawberries and grapes.

In Latin America pesticide use is increasing due to pressures to enhance agroexports. If current globalization trends continue, the pest control cost for Latin America is expected to reach US$ 4 billion by 2001. Several studies alarmingly confirm the widespread risks that pesticide exposure inflicts on small farmers, farmworkers and their families.

The reliance on pesticides to deal with crop pests has created the need to continually develop new pesticides. As a pesticide is used again and again, a certain percentage of the target pest is able to survive because of a natural resistance to the chemical. It doesn’t take too long before a large portion of the target weeds, insects, or other pests become resistant to the pesticide. This keeps the farmer on a ‘pesticide treadmill’ as the older pesticides lose their effectiveness and new ones need to be used.

Fertilizers have been praised as being responsible for the temporary increase in food production observed in many countries. National average rates of nitrogen applied to most arable lands fluctuate between 120-550 kg N/ha (110 to 490 lb N/A). But bountiful harvests created at least in part through the use of synthetic fertilizers have associated environmental costs. Research has shown that increased application of chemical fertilizers leads to higher incidence of insects and diseases. Chemically fertilized crops exhibit higher foliage levels of free-N making them more susceptible to pests.

Two main reasons why synthetic fertilizers pollute the environment are their wasteful application and the fact that crops use them inefficiently. A significant amount of fertilizer that is not recovered by the crops ends up in a surface or groundwater. Nitrate contamination of aquifers is widespread and in dangerously high levels in many rural regions of the world. It is estimated that more than 25 percent of the drinking water wells in the United States contain nitrogen in the nitrate form above the safety standard of 10 parts per million. Such nitrate levels are hazardous to human health, and studies have linked nitrate uptake to methemoglobinemia (low blood oxygen levels) in children and to gastric, bladder, and esophageal cancers in adults.

It is estimated that about 50-70 percent of all nutrients that reach surface waters in the United States are derived from fertilizers. Fertilizer nutrients that enter surface waters (rivers, lakes, bays) can promote eutrophication, characterized usually by a population explosion of algae. Algal bloom turn the water bright green, sometimes prevent light from penetrating beneath surface layers, and therefore kills plants living on the bottom. Such dead vegetation serves as food for other aquatic microorganisms which soon deplete water of its oxygen, inhibiting the decomposition of organic residues, which accumulate on the bottom. Eventually such nutrient enrichment of freshwater ecosystems can lead to the destruction of all animal life in the water systems. In the Gulf of Mexico there is a huge ‘dead zone’ extending from the mouth of the Mississippi River to the west, where the excessive nutrients from farmland are believed to be
responsible for oxygen depletion. It is also believed that excess nutrients may stimulate populations of the very toxic form of Pfiesteria, an organism that kills fish and is harmful to humans.

Synthetic nitrogen fertilizers can also become air pollutants, and have recently been implicated in contributing to the destruction of the ozone layer and global warming. Their excessive use causes soils to become more acidic and also leads to nutritional imbalances in plants, resulting in a higher incidence of damage from insect pests and diseases.

It is clear then that the first wave of environmental problems is deeply rooted in the prevalent socioeconomic system that promotes monocultures and the use of high-input technologies and agricultural practices that lead to natural resource degradation. Such degradation is not only an ecological process, but also a social and political-economic process. Therefore, the problem of agricultural production cannot be regarded only as a technological one; attention to social, cultural, political, and economic issues that account for the crisis is crucial. This is particularly true today where the economic and political domination of the rural development agenda by agribusiness had thrived at the expense of the interests of farm workers, small family farms, rural communities, the general public, wildlife, and the environment.

The Second Wave of Environmental Problems

Despite the awareness of the impacts of industrial agriculture on the environment, some still argue for further intensification to meet the requirements of agricultural production in the twenty-first century. It is in this context that supporters of Astatus quo agriculture@ celebrate the emergence of biotechnology as the latest magic bullet, which will revolutionize agriculture with products based on nature=s own methods, making farming more environmentally friendly and more profitable for the farmer. Although certain forms of biotechnology may hold promise for an improved agriculture, under the control of multinational corporations it is more likely that the results will be the further industrialization of agriculture, increased environmental harm and the intrusion of private interests into public-interest sector research.

It is ironic that the biotech revolution in agriculture is being promoted by the same corporate interests (Monsanto, Novartis, DuPont) that championed the first wave of chemically-based agriculture. They now claim that by genetically modifying plants they can reduce chemically intensive farming and help develop a more sustainable agriculture. However, their practices to date do not instill great confidence in the supposedly benign effects of their products on the environment. The companies are developing products (various crop varieties) that produce immense profits while completely fitting in with the approaches which have been so harmful in the past. For example, two of the main thrusts of agricultural biotechnology have been the production of crop varieties that are either resistant to herbicides (so farmers will purchase and use more of the company=s weed killing chemicals) or contain a toxin that kills potential insect=s pests (in which case less insecticide is needed). The advantage claimed for the herbicide resistant crops is that the newer herbicides are less toxic than some of the older ones. However, such biotechnological products will do nothing but reinforce the pesticide treadmill in agroecosystems, thus legitimizing the concerns that many scientists have expressed regarding the possible environmental risks of genetically engineered organisms. When genes for the insect toxin from bacteria Bacillus thuringensis (Bt) are incorporated into plants, the plants produce a toxin and feeding insects can be killed. Although less insecticide will be needed for Bt crops, their use can create other problems (see below).
So far, field research as well as predictions based on ecological theory indicate that the major environmental risks associated with the release of genetically engineered crops can be summarized as follows:

(1) The economic tendencies of corporations is to create broad international markets for a single product, thus creating the conditions for genetic uniformity in rural landscapes. History has repeatedly shown that a huge area planted with a single variety is very vulnerable to a new matching strain of a pathogen or insect pest.

(2) The spread of such crops threatens crop genetic diversity by simplifying cropping systems and promoting genetic erosion as older varieties become extinct.

(3) There is potential for the unintended transfer to plant relatives of the added genes with unpredictable ecological effects. The transfer of genes from herbicide resistant crops to wild or semi-domesticated relatives through cross-pollination can lead to the creation of super weeds.

(4) Most insect pests will quickly develop resistance to the Bt toxin. Several moth species have been reported to have developed resistance to Bt toxin in both field and laboratory tests, suggesting that major resistance problems are likely to develop in Bt crops. The farmers that face the greatest risk from the development of insect resistance to Bt are neighboring organic farmers who grow corn, cotton or soybeans without agrochemicals. Once resistance appears in insect populations, organic farmers will not be able to use Bacillus thuringiensis in its microbial insecticide form to control Lepidoptera pests that move in from adjacent transgenic fields.

(5) Massive use of B.t. toxin in crops can unleash potential negative interactions affecting ecological processes and non-target organisms. Studies conducted in Switzerland show that Bt crops exerted mortality on predaceous lacewings raised on Bt-fed prey. These findings are of concern to small or organic farmers that rely for insect pest control on the rich complex of predators and parasites associated with their mixed plantings. Predators that move within and between mixed crop cultivars will encounter BT-containing nontarget prey throughout the season, potentially disrupting natural pest control mechanisms and thus making farmers dependent on pesticides.

(6) Bt toxins can also be incorporated into the soil through leaf materials and litter, where they may persist for two to three months, resisting degradation by binding to soil clay particles while maintaining toxic activity, in turn negatively affecting soil organisms and nutrient cycling. The fact that Bt retains its insecticidal properties persisting bound to soil particles for at least 230 days, is of serious concern to small farmers who cannot purchase expensive chemical fertilizers. Instead they rely on local organic residues and soil biota for soil fertility, which can be negatively affected by the soil bound toxin.

(7) A potential risk of plants containing introduced genetic material from viruses opens the possibility of new virus strains developing when viruses that infect the plant combine with the viral genes introduced by biotech companies.
(8) Another important environmental concern associated with the large-scale cultivations of virus-resistant, genetically modified crops relates to the possible transfer via flower pollen of virus-derived genes into wild plant relatives.

Although there are many unanswered questions regarding the impact of the release into the environment of plants and micro-organisms containing genes from other organisms, it is expected that biotechnology will exacerbate the problems of conventional agriculture, and by promoting monocultures will also undermine ecological methods of farming such as rotation and polycultures (where two or more crops are grown together). Because genetically modified crops developed for pest control emphasize the use of a single control mechanism, which has proven to fail over and over again with insects, pathogens, and weeds, these crops are likely to increase the use of pesticides and to accelerate the evolution of super weeds and resistant insect pest strains. The possibilities are worrisome, especially when considering that in 200 the global area devoted to genetically modified crops reached 42 million hectares with United States, Canada and Argentina leading the way. In most countries prudent safety standards to monitor such releases are absent or are inadequate to prevent or even predict ecological risks. In the industrialized countries from 1986-1992, over half of all field trials to test genetically modified crops involved herbicide tolerance. As Roundup (made by Monsanto) and other broad spectrum herbicides are increasingly used on cropland, the options for farmers for a diversified agriculture will be even more limited.

The Barriers for the Implementation of Alternatives

The agroecological approach seeks the diversification and revitalization of medium size and small farms and the reshaping of the entire agricultural policy and food system in ways that are economically viable to farmers and the general public. In fact, throughout the world there are hundreds of movements that are pursuing a change toward ecologically sensitive farming systems from a variety of perspectives. Some emphasize the production of organic products for lucrative markets, some land stewardship, while others promote the empowerment of peasant communities. In general, however, the goals are usually the same; to secure food self-sufficiency, to preserve the natural resource base, and to ensure social equity and economic viability.

Some well-intentioned groups suffer from technological determinism, and emphasize the development and dissemination of low-input or appropriate technologies. Somehow, it is believed, these technologies in themselves have the capability of initiating beneficial social changes. The organic farming school that emphasizes input substitution (i.e. a biological insecticide substituted for a more toxic synthetic one), but leaves the monoculture structure untouched, epitomizes those groups that have a relatively benign view of capitalist agriculture. Such a perspective has unfortunately prevented many groups from understanding the structural roots of environmental degradation linked to monoculture farming.

The acceptance of the present structure of agriculture as a given condition restricts the real possibility of implementing alternatives that challenge such a structure. Thus options for a diversified agriculture are inhibited by, among other factors, the present trends in farm size and mechanization. Implementation of such mixed agriculture would only be possible as part of a broader program that includes land reform and farm machinery redesigned for polycultures. Merely introducing alternative agriculture designs will do little to change the underlying forces
that led to monoculture production, farm size expansion, and large-scale mechanization in the first place.

Similarly, obstacles to changing cropping systems have been created by the government commodity programs in place these last decades. The programs rewarded those who maintained monocultures of grain by assuring these producers a particular price for their product. Those who failed to plant the allotted acreage of corn and other price-supported crops lost area from their allowed Abase,@ on which future subsidies would be paid. This reduced their potential income from the price-support program. Consequently the programs created a competitive disadvantage for those who used a crop rotation. Although the price-support system is being phased out, the pattern it helped to develop is very well established.

On the other hand, the large influence of transnational corporations (TNCs) in promoting sales of agrochemicals cannot be ignored as a barrier to sustainable farming. Most TNCs have taken advantage of existing policies that promote the enhanced participation of the private sector in technology development and delivery, putting themselves in a powerful position to scale up promotion and marketing of pesticides. Given such a scenario, it is clear that the future of agriculture will be determined by power relations, and there is no reason why farmers and the public in general, if sufficiently empowered, could not influence the direction of agriculture toward goals of sustainability.

Conclusions

The nature of the modern agricultural structure and contemporary policies have strongly influenced the context of agricultural technology and production, which in turn has led to numerous environmental problems. Given the realities of capitalism, resource-conserving practices are discouraged and in many cases such practices are not profitable for farmers. The expectation that a set of policy changes could bring a renaissance of diversified or small-scale farms may be unrealistic, because it negates the existence of economies of scale in agriculture and ignores the political power of agribusiness corporations and current globalization trends. A more radical transformation of agriculture is needed, one guided by the notion that ecological change in agriculture cannot be promoted without comparable changes in the social, political, cultural, and economic arenas that also constrain agriculture. Change toward a more socially just, economically viable, and environmentally sound agriculture will be the result of social movements in the rural sector in alliance with urban organizations.