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Ecological Impacts of Modern Agriculture in the United States and Latin America

Miguel A. Altieri and Clara Ines Nicholls

Introduction

During the last two decades, interest in sustainable agriculture has grown to worldwide proportions, with various sectors of society slowly realizing that agrochemical technologies, resource scarcity, environmental degradation, uncontrolled economic growth, etc., are seriously threatening the long-term limits of agricultural expansion. Although these problems affect most regions in the world, their intensity or perceived importance differs in each area, as does the motivation behind the pursuit of sustainable agricultural development. Clearly, in industrialized countries (ICs) a major factor has been the need to deal with the consequences of technology-induced environmental degradation resulting from a sort of "development oversaturation." Conversely, in developing countries (LDCs), although IC's environmental problems are common in commercial agricultural areas, historically speaking, "development" has not reached the vast population of resource-poor farmers. Therefore, there is a great need to match agricultural development with the needs of this large and impoverished sector of society (Redclift 1989).

Today, 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 (Conway and Pretty 1991). Evidence has accumulated showing that whereas the present capital and technology-intensive farming systems have been extremely productive and able to furnish low-cost food, they also bring a variety of economic, environmental and social problems (Audirac 1997).

Evidence also shows that the very nature of the agricultural structure and prevailing policies in a capitalist setting have led to an 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 (Pretty 1995). In turn, lack of rotations and diversification take away key self-regulating mechanisms, turning monocultures into highly vulnerable agroecosystems dependent on high chemical inputs (Gliessman 1997).

The expansion of farm specialization and monocultures has 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 (Vallve, 1993). Available data indicate that the amount of crop diversity per unit of arable land has decreased and that croplands have shown a tendency toward concentration. The conventional mode for industrial agriculture in Latin America, especially the so-called 'Green Revolution' has emphasized the application of a reductionist scientific paradigm focusing on high yielding varieties (HYVs) that depend on purchased packages of chemical, mechanical and energy inputs. Yield maximization, uniformity of genetic resources and crop varieties, and simplification of farming systems have, for decades, driven technical innovation (Thrupp 1998). 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 agriculture to serve international markets (McIsaac and Edwards1994).

In Latin America, as countries are pulled into the existing international order and change policies in order to serve the unprecedented debt, governments increasingly embrace neoliberal economic models that promote export-led growth (Altieri and Masera 1993). Despite the fact that in some countries such as Argentina, Chile, and Mexico the model appears successful at the macroeconomic level, deforestation, soil erosion, industrial pollution, pesticide contamination and loss of biodiversity (including genetic erosion) proceed at alarming rates and are not reflected in the economic indicators. So far there is no clear system to account for the environmental costs of such development models (LACDE 1990).

The technologies allowing the shift toward specialization and monoculture have been 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 have encouraged the acceptance and utilization of these technologies (Buttel and Gertler 1982). And economic liberalization, open markets and reduction of trade barriers have all been forces triggering agricultural specialization in Latin America. In addition, the largest agribusiness corporations have found that concentrating certain processing facilities for a given product (chickens, hogs, or wheat) in specific countries produces more profits, which lead to more farm and regional specialization (Murray 1994).

The First Wave of Environmental Problems

The specialization of farms has led 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, have negatively impacted the environment and rural society. A number of what might be called "ecological diseases" have been associated with the intensification of food production.

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 alkalization (especially in arid and semi-arid regions), pollution of surface and groundwater, 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 (Conway and Pretty 1991). Each "ecological disease" is usually viewed as an independent problem, rather than what it really is—a symptom of a poorly designed and poorly functioning agroecosystem.

Under conditions of intensive management, treatment of such "ecological diseases" 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 United States alone), is a symptom of the environmental crisis affecting agriculture (Pimentel and Lehman 1993).

Pesticides

Cultivated plants grown in genetically homogenous 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 (Altieri 1995). 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 costs (impacts on wildlife, pollinators, natural enemies, fisheries, water, and development of resistance) and social costs (human poisonings and illnesses) of pesticide use reach about $8 billion each year (Pimentel and Lehman 1993).

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 was in particularly toxic pesticides, many of which are linked to cancers, used on such crops as strawberries and grapes (Liebman 1997).

In Latin America, pesticide use in general is increasing, especially in large scale production systems. Pesticide sales more than doubled in the region between 1976 and 1980 (IRL 1981), exceeding industry predictions (Farm Chemicals 1976). There was a continuous growth in consumption, both through importation and domestic production, throughout the 1980s. Latin America's share of the global pesticide market, currently around 10 percent, is steadily increasing. Brazil alone accounts for nearly 50 percent of the total sales in the region, followed by Mexico, Argentina, and Colombia. From 1980 to 1986, pesticide sales rose dramatically in Brazil and Argentina. If current trends continue, the cost to Latin America of chemical pest control is expected to reach US $3.97 billion by the year 2000 (Maltby 1980).

Such increased use of pesticides has had a heavy human toll. Self reported rates of pesticide intoxication from surveys in Latin America run at about 13 percent of agricultural workers per year. Pesticide poisonings among children under 18 years of age accounts for roughly 10–20 percent of all poisonings. Several studies conducted throughout the region alarmingly confirm the widespread risks that pesticide exposure inflicts on farmworkers and their families (McConnell et al. 1993).

Fertilizers

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. But increased fertilizer use is quickly approaching the point of diminishing yield returns. In the case of Chile in 1988 about 316 thousand tons of chemical fertilizers were used. In eight years, urea exhibited a 764 percent increase in use, mostly for application in cereals. Although between 1985–1990, wheat received 62 percent more fertilizer than in the previous decade, this resulted only in a 3.1 percent increase in yields (Altieri and Rojas 1994). This is a clear indication of yield leveling off and in some cases even declining despite the use of higher amounts of fertilizers. Such processes have been linked to fertilizer-induced soil degradation (McGuiness 1993).

The bountiful harvests created at least in part through the use of synthetic fertilizers have associated environmental costs. 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 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 metahemoglobinemia (low blood oxygen levels) in children and to gastric, bladder, and esophageal cancers in adults (Conway and Pretty 1995).

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 an explosion of algae. Algal blooms turn the water bright green, sometimes prevent light from penetrating beneath surface layers, and therefore kill plants living on the bottom. Such dead vegetation serves as food for other aquatic microorganisms, soon depleting water of its oxygen and inhibiting the decomposition of organic residues, which accumulate on the bottom (McGuiness 1993).

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 (McGuiness 1993).

Synthetic nitrogen fertilizers can also become air pollutants and have recently been implicated in contributing to global warming and the destruction of the ozone layer. 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 (McGuiness 1993, Conway and Pretty 1995).

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 (Buttel and Gertler 1982). 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 has thrived at the expense of the interests of farmworkers, small family farms, rural communities, the general public, wildlife, and the environment.

The Second Wave of Environmental Problems

Despite increased awareness of the impacts of modern technologies on the environment as we trace pesticides in food chains and crop nutrients in surface waters and aquifers, some scientists 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 "status 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 hold promise for an improved agriculture, under the control of multinational corporations it is more likely that the results will be increased environmental harm, the further industrialization of agriculture, and the intrusion of private interests too far into public-interest sector research (Kenny and Buttel 1985, Hobbelink 1991).

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 various crop varieties that produce immense profits while continuing to adhere to 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 (HRCs), so farmers will purchase and use more of the company's weed-killing chemicals, or contain a toxin that kills potential insect pests, in which case less insecticide is needed but threatens the viability of *Bacillus thuringiensis* (Bt), a useful microbial insecticide.

The global arable land area devoted to transgenic crops increased 4.5 fold from 2.8 million hectares in 1996 to 12.8 million hectares in 1997, and no less than 40 million hectares in 1999. The United

States accounted for 64 percent of the global acreage, followed by China and Argentina. HRCs and Bt crops accounted for 54 and 31 percent of the total global area in 1997. Increasingly, large tracts of transgenic soybean (18 million hectares), maize (10 million hectares), potato, tomato, tobacco, and cotton are being commercially deployed in agricultural landscapes worldwide (James 1997).

The advantage claimed for the HRCs is that the newer herbicides are less toxic than some of the older ones. USDA statistics show that in 1997 expanded plantings of Roundup Ready soybeans resulted in a 72 percent increase in the use of glyphosate, a disturbing trend given evidence that promoted herbicides such as bromoxynil and glyphosate pose risks. Bromoxynil causes birth defects in laboratory animals, is toxic to fish, and may cause cancer in humans. Because bromoxynil is absorbed through the skin, and because it causes birth defects in rodents, it is likely to pose hazards to farmers and farm workers. Similarly, glyphosate has been reported to be toxic to some non-target species in the soil—both to beneficial predators such as spiders, mites, carabid and coccinellid beetles and to detritivores such as earthworms, as well as to aquatic organisms, including fish (Rissler and Mellon 1996). Given that this herbicide is known to accumulate in fruits and tubers as it suffers little metabolic degradation in plants, questions about food safety also arise. Oncologists in Sweden have gathered some evidence that links exposure to glyphosate and the incidence of Non-Hodgkin Lymphoma (Lappe and Bailey 1998). Given these problems, it is expected that 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 the bacteria Bt are incorporated into plants, the plants produce the toxin and feeding lepidoptera insects can be killed. Although less insecticide will be needed for Bt crops, their use can create other problems (Hilbeck et al. 1998)

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 (Krimsky and Wrubel 1996, Snow and Moran 1997, Kendall et al. 1997):

- The trends set forth by 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 (Robinson 1996).
- The rapid and massive spread of such crops (about 40 million hectares worldwide in 1999) threatens crop genetic diversity by simplifying cropping systems and promoting genetic erosion as older varieties become extinct.
- There is potential for the unintended transfer to plant relatives of the added genes with unpredictable ecological effects. The transfer of genes from HRCs to wild or semi-domesticated relatives (through cross-pollination) can lead to the creation of super weeds. This problem is even more serious in Latin American countries that serve as centers of origin of crop diversity, as the probability for transgenic crops to encounter sexually compatible wild relatives is very high (Radosevich et al. 1996)
- Most insect pests will quickly develop resistance to the Bt toxin. Several moth species have been reported to have developed resistance to the Bt toxin in both field and laboratory tests, suggesting that major resistance problems are likely to develop in Bt crops.
- Massive use of the Bt toxin in crops can unleash potential negative interactions affecting ecological processes and non-target organisms. Studies conducted in Scotland suggest that aphid pests were capable of transferring the toxin from Bt crops to a beneficial beetle that feeds on the aphid. This decreased reproduction and longevity of the beneficial beetle. Similarly, studies in Switzerland show that mean total mortality of lacewing larvae (Chrysopidae) raised on Bt-fed prey was 62 percent compared to 37 percent when raised on Bt-free prey. These Bt, prey-fed Chrysopidae also exhibited prolonged development time throughout their immature life stage (Hilbeck et al. 1998).
- Pollen from Bt crops carried by wind and deposited on wild plants can eliminate natural populations of insect herbivores, as suggested by a recent Cornell study which showed that 44 percent of the monarch butterfly caterpillars eating milkweed leaves artifi-

cially dusted with Bt corn pollen died after four days of exposure (Losey et al. 1999).

- 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 (Donegan and Seidler 1999).
- 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 (Snow and Moran 1997).
- Another important environmental concern associated with the large-scale cultivation of virus-resistant, genetically modified crops relates to the possible transfer via flower pollen of virus-derived genes into wild plant relatives. The possibility that transgenic virus-resistant plants may broaden the host range of some viruses or allow the production of new virus strains through recombination and transcapsidation demands careful further experimental investigation.

Although there are many unanswered questions regarding the impact of the release into the environment of plants and microorganisms 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 rotations and polycultures. 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 accelerate the evolution of “super weeds” and resistant insect pest strains (Altieri 2000). These possibilities are disquieting, especially when considering that in 1999, the global area devoted to genetically modified crops reached 40 million hectares. Seventy-two percent of the 25,000 genetically modified crops field trials were conducted in descending order, in Europe, Latin America, and Asia (James 1997). In most countries 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. The promises of spectacular yields were not significantly different in genetically modified versus non-modified crops in 12 of 18 crop/region combinations according to the USDA's Economic Research Service. 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.

Concluding Remarks

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 (Buttel and Gertler 1982). In Latin America, policies and new economic pressures that emphasize agroexport production through specialized, large-scale monocultures, are enhancing demand and use of pesticides to an expected level of US $3.97 billion by the year 2000 (Murray 1994).

A true reduction and/or elimination of pesticide use in the agroexport sector will require major political reforms that deal with the main forces that push farmers to use chemicals: government pesticide subsidies, corporate control of agricultural enterprises, research serving the needs of the private sector rather than the public sector, internationally set unrealistic cosmetic standards, etc. There are many successful examples of biological pest control implemented in Latin America (i.e. sugarcane pests in Colombia and Brazil, wheat aphids in the American southern cone, multiple biocontrol efforts in Cuba etc.) which show the environmental soundness, cost-effectiveness and permanent effect of ecologically based pest management (EBPM) approaches (Nicholls and Altieri 1997).

Dramatic changes in policies and political will are necessary to reorient research, training and extension in EBPM and to scale up to a massive level a transformation of agriculture to a more sustainable mode. But pesticide reduction should go hand in hand with new farming system practices and designs that better utilize scarce water and nutrients, minimize soil erosion and water pollution, and encourage biodiversity as a key element in the strengthening of agroecosystems against pests (Altieri 1994). Coalitions of farmer organizations, NGOs, and consumer groups will be essential to put pressure on governments and on MNCs which actively promote formulation and sales of pesticides, to discourage bias towards pesticides and to encourage alternative practices. Given the realities of globalization, resource-conserving practices are discouraged, and in many cases such practices are not profitable for farmers.

As the large-scale landscape homogenization with transgenic crops proceeds, environmental impacts will probably be substantial, and it is expected that such massive deployment will exacerbate the ecological problems already associated with monoculture agriculture. Unquestioned expansion of this technology into developing countries is also undesirable. There is strength in the agricultural diversity of many of these countries, and it should not be inhibited or reduced by extensive monoculture, especially when consequences of doing so result in serious social and environmental problems (Altieri 2000).

Many environmental groups have argued for the creation of suitable regulation to mediate the testing and release of transgenic crops to offset environmental risks and demand a much better assessment and understanding of ecological issues associated with genetic engineering. This is crucial as many results emerging from the environmental performance of released transgenic crops suggest that in the development of "resistant crops," not only is there a need to test direct effects on the target insect or weed, but the indirect effects on the plant (i.e. growth, nutrient content, metabolic changes), soil, and non-target organisms must also be evaluated. Unfortunately, funds for research on environmental risk assessment are very limited. For example, the USDA spends only 1 percent of the funds allocated to biotechnology research on risk assessment, about $1-2 million per year. Given the current level of deployment of genetically engineered plants, such resources are not enough to even discover the "tip of the iceberg."

Many scientists and sustainable agriculture advocates demand continued support for ecologically based agricultural research, as all the biological problems that biotechnology aims at can be solved using agroecological approaches. The dramatic effects of rotations and intercropping on crop health and productivity, as well as of the use of biological control agents on pest regulation have been confirmed repeatedly by scientific research (Altieri and Rosset 1995). The problem is that research at public institutions increasingly reflects the interest of private funders at the expense of good public research such as biological control, organic production systems and general agroecological techniques. Civil society must request more research on alternatives to biotechnology by universities and other public organizations. There is also an urgent need to challenge the patent systems and intellectual property rights intrinsic to the WTO which not only provide multinational corporations with the right to seize and patent genetic resources but that will also accelerate the rate at which market forces already encourage monocultural cropping with genetically uniform transgenic varieties. Based on history and ecological theory, it is not difficult to predict the negative impacts of such environmental simplification on the health of modern agriculture.

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In Territories, Commodities and Knowledges: Latin American Environmental Histories in the Nineteenth and Twentieth Centuries, ed. Brannstrom, Christian, 121â€“47. London: Institute for the Study of the Americas, 2004.Â Tucker, Richard P.Insatiable Appetite: The United States and the Ecological Degradation of the Tropical World. Berkeley: University of California Press, 2000. Browder, John, and Godry, Brian. This article is part of series on the. United States portal. v. t. e. Agriculture is a major industry in the United States, which is a net exporter of food. As of the 2007 census of agriculture, there were 2.2 million farms, covering an area of 922 million acres (1,441,000 sq mi), an average of 418 acres (169 hectares) per farm. Although agricultural activity occurs in every state in the union, it is particularly concentrated in the Great Plains, a vast expanse of flat, arable land in the center of These three features of modern agricultureâ€"control of crops and their genetics, of soil fertility via chemical fertilization and irrigation, and of pests (weeds, insects, and pathogens) via chemical pesticidesâ€"are the hallmarks of the green revolution. They have caused four once-rare plants (barley, maize, rice, and wheat) to become the dominant plants on earth as humans became the dominant animal.Â For comparison, the total forested area of the United States, including Alaska, is 298 million hectares. Entire regions of the world now are dominated by virtual monocultures of a given crop.Â The long-term ecological impacts of increased rates of agricultural nitrogen and phosphorus input will depend on the levels to which these nutrients accumulate in various nonagricultural ecosystems.