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The Environmental Costs of Agricultural Trade Liberalization: Mexico-U.S. Maize Trade Under NAFTA

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The Working Group on Development and Environment in the Americas, founded in 2004, brings together economic researchers from several countries in the Americas who have carried out empirical studies of the social and environmental impacts of economic liberalization. The Working Group's goal is to contribute empirical research and policy analysis to the ongoing policy debates on national economic development strategies and international trade. The Working Group held its inaugural meeting in Brasilia, March 29-30, 2004. This paper is one of eight written for the Brasilia meetings. They are the basis for "**Globalization and the Environment: Lessons from the Americas**," a policy report published by the Heinrich Böll Foundation in July 2004.

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Abstract

The North American Free Trade Agreement (NAFTA) had a profound impact on maize trade between the United States and Mexico. Negotiated tariff reductions and the Mexican government's decision not to charge some tariffs to which it was entitled resulted in a tripling of US exports to Mexico. This paper examines the environmental implications of this change on both sides of the border, summarizing previous research on the subject and, in the case of Mexico, contributing new data on the key question of the links between NAFTA, poverty, migration, and genetic diversity.

For the US, increased exports to Mexico due to trade liberalization represent 1.3% of total US production and should therefore be considered responsible for 1.3% of the environmental impacts of corn production. These are considerable, including: high chemical use; water pollution due to runoff; unsustainable water use for irrigation; the expansion of genetically modified corn; soil erosion; and biodiversity loss. Trends in these areas are presented. For Mexico, the principal potential environmental impact of the loss of a significant share of its domestic maize market to the US is the threat to agrobiodiversity. Preliminary evidence is presented on the extent to which imports and declining prices are reducing the capacity to produce native corn varieties.

These changes are placed within an analytical framework that recognizes the possibility that the flow of environmentally unsustainable economic activity in the case of increasing agricultural trade could be the reverse of that assumed in the standard pollution haven scenario, with net environmental costs for the trading partners as a group. We also locate this market-based competition within an analysis of the positive and negative environmental externalities associated with Mexican and US production methods respectively. The result in the liberalized North American market is competition that exacerbates the economic and environmental impacts of those distorted markets. Market failures in one area – negative externalities in the US – interact with market failures in another – positive externalities in Mexico – to create a net environmental impact that is greater than the sum of its parts – the globalization of market failure.

We conclude with an analysis of the extent to which this framework can be useful in the analysis of other crops, other countries, and other trade agreements.

Introduction

Ten years have passed since the North American Free Trade Agreement (NAFTA) took effect, and its environmental and social impacts continue to be the topic of fierce debate. Nowhere is this truer than in the area of agricultural trade in general and trade in maize in particular. While no one disputes the figures that show a significant rise in US maize exports to Mexico since 1994, many still argue that the agreement itself was largely not responsible for those changes. Environmental and social impacts are even more hotly debated. How much of the environmental costs of increased corn production in the United States should be ascribed to NAFTA? While most agree on the high environmental costs of US corn production, there is debate over NAFTA's influence. In Mexico, the debate centers on the threat to agro-biodiversity in maize. While many say the declines in producer prices and government support programs threaten to provoke an exodus from traditional corn production – with the resulting loss of diversity – others suggest that traditional producers are remaining on their farms and that maize diversity is not threatened.

In this paper, we attempt to answer these fundamental questions, while placing the changing trade in maize under NAFTA within an analytical framework that can provide more general lessons about globalization and its impact on the environment. We examine the NAFTA-induced shift in maize trade and production in the US and Mexico. We assess the environmental impacts of that change for each country, summarizing previous research on the subject and, in the case of Mexico, contributing new data on the key question of the links between NAFTA, poverty, migration, and genetic diversity.

We place this analysis within a new analytical framework. We place the assessment of the environmental impacts of changing maize production patterns in the context of positive and negative environmental externalities associated with traditional versus industrial agriculture. As globalization brings two vastly different forms of production into direct contact – and direct competition – we see what Boyce has called the globalization of market failure (Boyce 1999). We conclude with some implications for agricultural trade liberalization.

An Analytical Framework

The concept most widely associated with the effects of trade on the environment is the pollution haven. According to this theory, rising trade and declining restrictions on the movement of capital and goods between an industrialized and a developing country will lead pollution-intensive companies to relocate production to areas in which regulations and/or enforcement of environmental laws are more lax. Following this theory, it was feared that NAFTA would produce an exodus of pollution-intensive industries from the US to Mexico to take advantage of Mexico's weaker environmental enforcement. This fear has largely not proven to be a widespread phenomenon, though there are certainly instances of dirtier industries relocating production to avoid stricter US environmental regulations. (See Copeland and Taylor 2003 for a good review of this literature.)

The assumption embedded in the pollution haven concept is that the flow of environmental degradation will be from North to South, from the more developed toward the less developed country. This is based on the assumption that cleaner technology and rising expectations for a clean environment will make practices in the North more sustainable than those in the South. As this paper highlights, this is a false assumption for at least some agricultural trade. Agricultural practices in US corn production are far less sustainable than the traditional Mexican practices of maize cultivation using – and continuing to steward – diverse seed varieties of benefit to humankind as a whole. The shift in corn production from Mexico to the US, a trend reinforced by NAFTA, has the net effect of increasing environmental degradation. It is worth noting that in this case, contrary to the common applications of the pollution haven hypothesis, trade has not brought cleaner production through the introduction of developed country technology. Rather, it has brought more environmentally damaging practices.

Economist James Boyce has offered an additional useful concept to the discussion of the environmental impacts of trade: the globalization of market failure. He bases his analysis on field studies of traditional jute production in Bangladesh, which is being displaced by imported synthetic fibers, and traditional corn production in Mexico, which is threatened by hybrid corn imports from the United States following trade liberalization. He argues that economic integration links imperfect markets in environmentally destructive ways. In both cases, the market prices for modern, Northern products fail to incorporate significant negative environmental externalities. The international economic playing field is tilted even further against traditional producers, who go uncompensated for the positive environmental externalities associated with traditional production. As trade – and trade agreements – brings together these two forms of production, distorted in opposite ways by environmental externalities, the result is unfair competition with net environmental costs. Boyce demonstrates, for example, that nearly the entire price advantage enjoyed by synthetics over jute – about 35 per cent – would be eliminated if environmental externalities were factored into prices (Boyce 1999).

As we will see in the case of changing maize trade between Mexico and the United States, the flow of pollution-intensive economic activity is from South to North. And economic liberalization, of which NAFTA is a key component, has fueled the globalization of market failure, increasing environmental damage in the United States while threatening an irreplaceable environmental (and economic) global good in the South – Mexico's rich reservoir of maize diversity.

The Importance of Maize

Corn is an extremely important agricultural product in both countries. In the US corn is one of the country's most important crops, with annual sales around \$17 billion, or 9% of the value of all agricultural output (NASS 2000). It is the most valuable agricultural product and accounts for more than a quarter of all farm receipts in the states of Iowa, Illinois, and Indiana, in the heart of the "corn belt"; it is among the top two or three farm products in many neighboring states (ERS 2001).

In terms of total acreage nationwide, corn is similar to soybeans and far ahead of all other crops: corn occupies 28 million hectares, more than 20 percent of all US harvested acreage, or about 3.7 percent of the total area of the contiguous 48 states. Corn and soybeans are often grown in rotation; together they account for more than 40 percent of harvested acreage, or 7.5 percent of the area of the contiguous US (Anderson, Magleby et al. 2000)

Corn exports account for roughly 20% of the corn crop, or \$5 billion in sales (FATUS 2001). The US is by far the world's largest corn producer and exporter, accounting for 40% of world production and 66% of world exports in 1999; in the same year Mexico accounted for 3% of world production and 7% of world imports (FAOSTAT 2001). In 2002 Mexico was second only to Japan as a market for US corn, absorbing 11% of US exports.

In Mexico corn production accounts for over two-thirds of the gross value of agricultural production. Corn covers half of the total area under cultivation for all crops (DIAGRO). Roughly 3 million people are employed in the cultivation of corn, more than 40 percent of the labor force involved in agriculture or about 8 percent of Mexico's total labor force (Nadal 2000). This supports some 18 million people.

Mexico has the world's second highest annual per capita corn consumption (127 kg), after Malawi (Morris 1998). The pattern of consumption in Mexico is distinct from the US and other industrial countries since 68% of all corn is directly used as food. In the world as a whole, just 21% of total corn production is consumed as food. In industrial countries, including the US, corn is more often used as livestock feed or as an industrial input – a trend that is just beginning to appear in Mexico.

In Mexico maize is the basic staple food for human consumption. One study found that on average about 59% of human energy intake and 39% of protein intake was provided by maize grain in the form of "tortilla" (cooked corn dough) (Bourges, 1992, in Turrent-Fernandez 1997). Five thousand years of maize domestication has generated more than 40 races of maize specialized for direct human consumption. By contrast, in the last hundred years, the industrialized countries have specialized in developing maize for animal consumption and industrial use (CIMMYT 2001).

Mexico is the ancestral home of maize, and possesses a unique and irreplaceable genetic diversity of varieties, or landraces. Most of the country's corn production comes from

traditional landraces cultivated by peasant farmers from seeds that they preserve from their own crops and from the exchange of seeds with neighbors in their communities (Wilkes, Yeatman et al. 1981; Serratos-Hernandez Juan Antonio 2001). Such *in situ* conservation of maize genetic resources is considered essential to the long-term security of this important food crop, which has particular economic value because it serves as the basis for crop breeding (Brush 2000).

Changing Maize Trade Under NAFTA

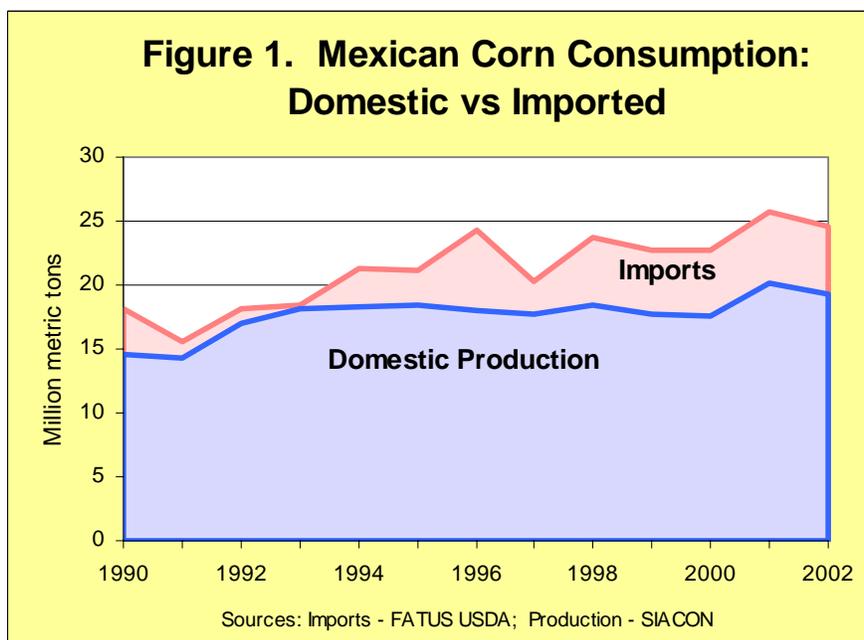
Maize and beans were included in NAFTA very late in the negotiations due to resistance within Mexico to liberalizing the country's two most important staple crops and food sources. Over farmer objections, Mexico agreed to liberalize maize and beans, along with other crops, using a tariff-rate quota (TRQ) system to phase in imports and phase out tariffs. Maize and beans got the maximum 15-year TRQ. For maize, the initial import quota was set at 2.5 million tons with 215% tariffs on imports above quota.¹ The quota was set to increase by 3% each year, reaching 3.6 million tons by 2008, while the tariffs on over-quota imports were negotiated to decrease gradually over the same period, reaching zero by 2008 (Nadal 2000).

The stated goal of the 15-year TRQ was to allow a slow transition to full competition, recognizing the wide productivity differences between US and Mexican maize producers. Those differences are dramatic. The US farms nearly four times the area and achieves yields over three times those in Mexico. This gives the US eleven times the production, which at the time NAFTA was passed sold for roughly half the price of Mexican maize. US farm subsidies also give US producers an advantage, with direct subsidies per hectare about three times the levels in Mexico (Wise 2004).

Claiming production shortfalls and inflationary pressures, the Mexican government declined to enforce any of the TRQs it had negotiated for agricultural products, including maize. For maize, the negotiated 15-year transition to free trade was eliminated (Nadal 2000). From NAFTA's inception in 1994 the TRQ was not enforced. Beginning in 1996, US exports to Mexico increased dramatically, from a pre-NAFTA average (1990-93) of 1.6 million tons to 6.3 million tons. With annual fluctuations, US exports have averaged around 5 million tons since 1996, a 323% increase from the pre-NAFTA period (FATUS 2003).

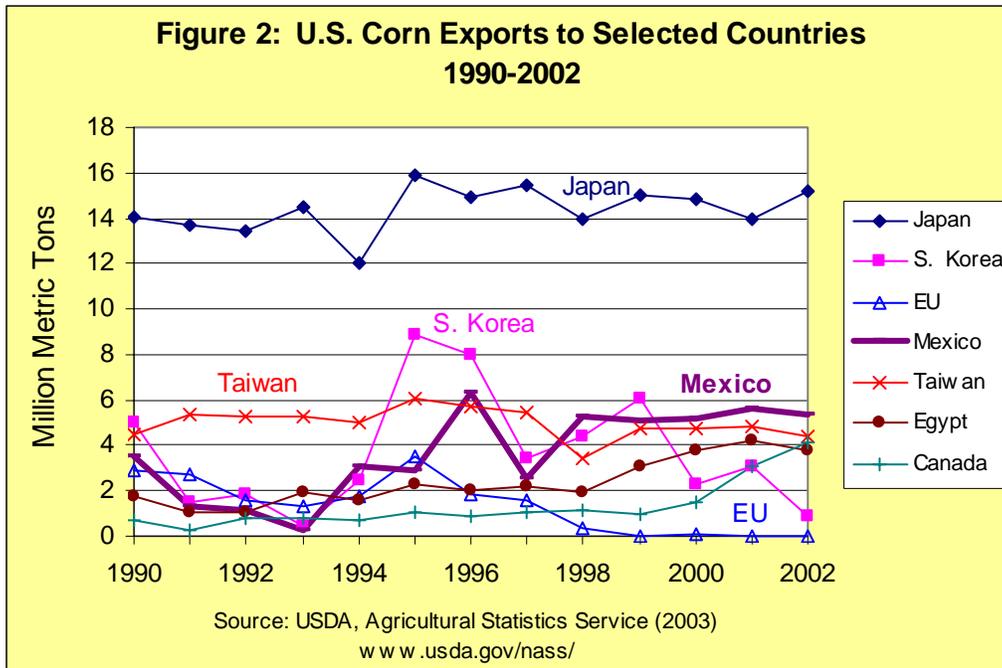
In Mexico, the flood of imports produced a significant drop in producer prices. Real prices fell by 25% in the years following NAFTA. By 2002 they were 47% below their pre-NAFTA levels (SIACON 2003).

¹ Note that this report uses metric units throughout, e.g. metric tons or kilograms for weight, and hectares for area. Unless otherwise noted, monetary amounts are in current US dollars.



This shift in production – from Mexico to the US – was more significant for Mexico than for the US. For Mexico, imports rose from 8.9% of total corn consumption in the pre-NAFTA period to 21.3%. In fact, the change was less a shift of production than a capturing of rising Mexican demand by US producers. As Figure 1 shows, Mexican maize production in this period did not decrease but stagnated at 18-19 million tons. The rise in imports fed increasing demand primarily for yellow corn for feed for a growing livestock industry, corn sweetener for an expanding beverage industry, and flour for the increasing production of processed foods (Nadal 2002). The growth in all these industries was related to growing trade relations with the US, stimulated in part by NAFTA.

For the United States, the economic importance of exports to Mexico was not insignificant. Prior to NAFTA, US maize exports to Mexico represented 0.8% of US production. In the post-NAFTA period, this share rose to 2.1%, two-and-a-half times the previous level. The increase in exports to Mexico came at a fortuitous time for US corn growers, who were experiencing a decline in export markets wary of genetically modified foods. Mexico banned the cultivation of GM corn in 1998, but imports are still allowed. As Figure 2 shows, declining exports to Europe and South Korea, which imposed restrictions on GM food imports, were partially compensated by the increase in exports to Mexico. By 2000, Mexico was the second most important export market for US maize after Japan, suggesting that the economic importance of NAFTA to US maize producers are of greater importance to the US than their size alone would suggest.



Environmental Impacts in the US

The changes since the adoption of NAFTA have resulted in an increase in exports to Mexico from 0.8% to 2.1% of total US corn production. Thus the growth in trade amounts to an additional 1.3% of the US corn crop, and can be credited with 1.3% of the impacts of corn production, both positive and negative, in the US. US corn production remained fairly stable during this period, so rising exports to Mexico did not result in an increase in corn production. Rather, rising Mexican demand prevented a possible decline due to reduced demand in other export markets.

For this paper, we use a broad approach in assessing NAFTA's impact, which is based on the assessment that NAFTA cannot be usefully separated from the set of trade liberalizing policies of which it is a part. NAFTA's North American Commission for Environmental Cooperation, in its analytical framework, calls for a broad interpretation of NAFTA's economic and environmental impacts, noting that even where the agreement did not have a direct effect it may have stabilized and reinforced trends already underway (NACEC 1999). Some analysts attribute a smaller portion of rising US exports to NAFTA, arguing that some of these increases would have occurred even without the tariff reductions under NAFTA. (See, for example, Porter 2002; Zahniser and Link 2002.) While recognizing the usefulness in some instances of isolating those impacts that are directly attributable to NAFTA's provisions, we adopt the broader approach in this study.

Fertilizer, pesticides, irrigation

Increased exports to Mexico after NAFTA have affected the environment, as well as the economy, of the US farm states. The additional 1.3% of the crop sold to Mexico after NAFTA –

and after the broader set of trade liberalizing policies of which the trade agreement is a part – can be considered responsible for 1.3% of the environmental impacts, as well as the economic impacts, of US corn production. The principal exception to this “1.3% rule” is the complex question of genetically modified (GM) corn, where sales to Mexico assume a greater importance because Mexico has remained open to GM grains while significant other markets have rejected them.

The environmental impacts of corn production have been extensively studied; see Runge (2002) for a thorough presentation and literature review, and Ackerman, Wise et al. (2003) for a more detailed description and analysis of these trends. Major issues of concern include:

1. agrochemical impacts resulting from fertilizers, herbicides, and pesticides;
2. potentially unsustainable levels of irrigation; and
3. the introduction of genetically modified organisms;
4. soil erosion;
5. biodiversity.

Agrochemical Impacts

US agriculture in general, and corn production in particular, rely on intensive application of fertilizers, herbicides, and insecticides. While these chemicals make a major contribution to agricultural productivity, they also create problems of water pollution, with risks to human health and natural ecosystems. In particular, runoff of excess nitrogen and phosphate fertilizer contaminates surface and groundwater supplies, by promoting algal growth which reduces the dissolved oxygen content (hypoxia) in the water making it difficult for fish or other wildlife to survive. The great quantities of nitrogen carried by the Mississippi River have been implicated in the large “dead zone” in the Gulf of Mexico where ocean life has been killed off (Keeney and Muller 2000; Runge 2002; Goolsby et al. 1999). Corn production is a major contributor to this effect both through direct nitrogen runoff from fertilizer application on farms and through the use of corn as a feed for livestock whose manure contributes to water pollution.

Atrazine, the most common herbicide used in corn production, among other crops – and the most common pesticide detected in groundwater nationwide – is an endocrine disrupter and possible human carcinogen (it causes cancer in rats). Exposure to atrazine creates risks for farm workers, consumers of corn products, and users of groundwater downstream from farm areas (EPA 2001a; Repetto and Baliga 1996; Ribaudo and Bouzaher 1994; Briggs 1992). Metolachlor and S-Metolachlor, both leading herbicides that will be discussed later, are possible human carcinogens (EPA 2000; Briggs 1992). Chlorpyrifos, the most common insecticide used on cornfields, is a neurotoxin that poses risks for children who are exposed to it at high levels; it is also used on other foods, and for residential cockroach and termite control (EPA 2001b; Briggs 1992).

USDA’s National Agricultural Statistical Service (NASS) publishes annual reports on the use of agricultural chemicals by state, with coverage varying by crop and year. For 2000 the report covered the 18 top corn-growing states, accounting for 93% of production. It found that nitrogen fertilizer was applied to 98% of planted corn acreage, compared to 84% for phosphates and 66%

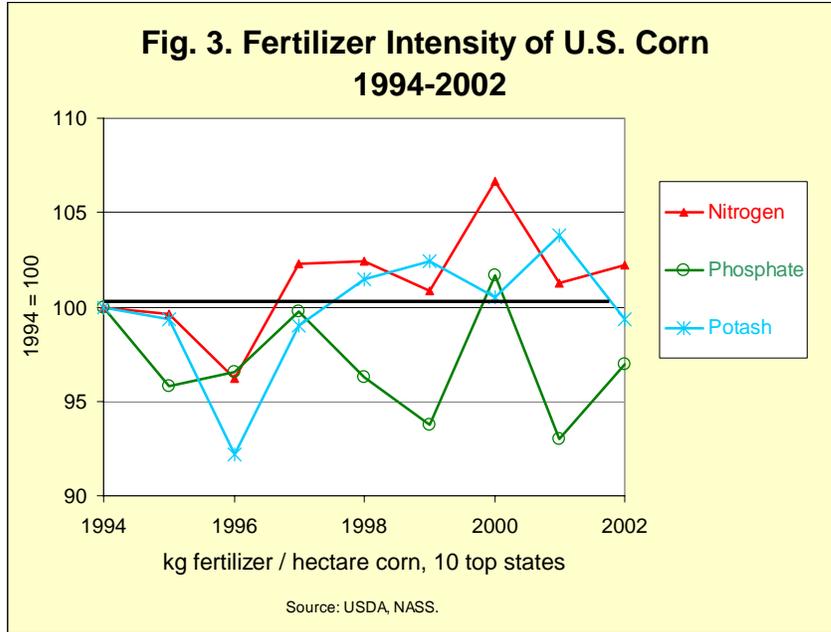
for potash, the three major varieties of fertilizer. Herbicides were applied to 97%, and insecticides to 29%, of corn acreage. Total quantities of chemical use, and chemical intensities (total quantity of chemical divided by total planted area), are shown in Table 1.

	Total Use (thousand metric tons)	Intensity (kg/hectare)
Nitrogen	4,423.7	148.18
Phosphate	1,577.4	52.84
Potash	1,716.3	57.49
Herbicides	69.6	2.33
Insecticides	4.5	0.15

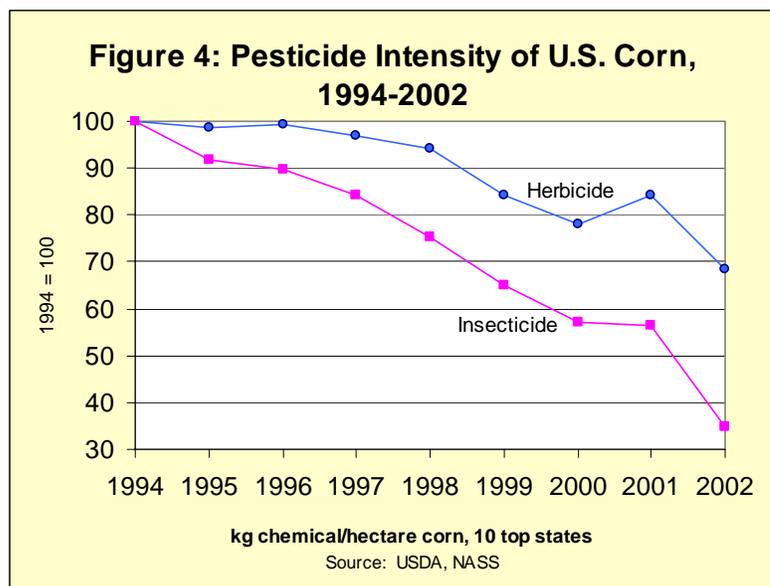
Source: USDA, National Agricultural Statistics Service

Three important conclusions emerge from these reports:

1. **Corn is more chemical-intensive than soybeans or winter wheat, by every available measure.** Using data for soybeans grown in 14 of the top corn states, and for wheat in 10 of the states, we see that in every state there is lower chemical use in soy or wheat than in corn. The averages show that there is little nitrogen fertilizer applied to soybeans, and little herbicide applied to wheat. The other ratios average from 33% to 58% -- that is, the other crops have from one-third to somewhat less than two-thirds the chemical intensity of corn (Ackerman, Wise et al. 2003).
2. **The fertilizer intensity of corn production has been relatively constant since 1994.** Turning to changes over time, consistent data on chemical use are available for every year from 1994 to 2002 for the top 10 corn producing states. Changes in fertilizer intensity for the 10 states as a whole are shown in Figure 1. These patterns are consistent with longer-term trends – over several decades, nitrogen use has been rising while phosphate and potash use have been roughly constant (Runge 2002). This implies that the serious, long-term problems of nitrogen runoff and its impacts on ground water in general, and the Mississippi River and the Gulf of Mexico in particular, will be worse, not because of increasing intensity but because of expanding production to meet rising demand in Mexico. If NAFTA-induced increases in US corn production represent 1.3% of US production and its environmental impacts, this represents 100,000 additional tons of nitrogen, phosphorous, and potassium-based loadings to US waterways each year.



3. **The herbicide intensity of corn production has dropped sharply since 1994, though the apparent drop in insecticide intensity is misleading.** As Figure 4 shows, the intensity of herbicide use has dropped steadily and sharply, with the intensity as of 2002 falling just below 70% of the 1994 value. The decline results from the ongoing process of innovation and change in the chemical industry (Benbrook 2001b). Of the herbicides used to treat corn, atrazine alone accounts for 35% by weight, while a group of chemicals called acetanilides account for another 40%; no other single category has nearly as large a share of the market. Innovation has occurred within the acetanilides, with new chemicals replacing similar older ones. This has allowed for estimated 35% reductions in application volumes, with a similar decrease in overall toxicity to humans (Ackerman, Wise et al. 2003).



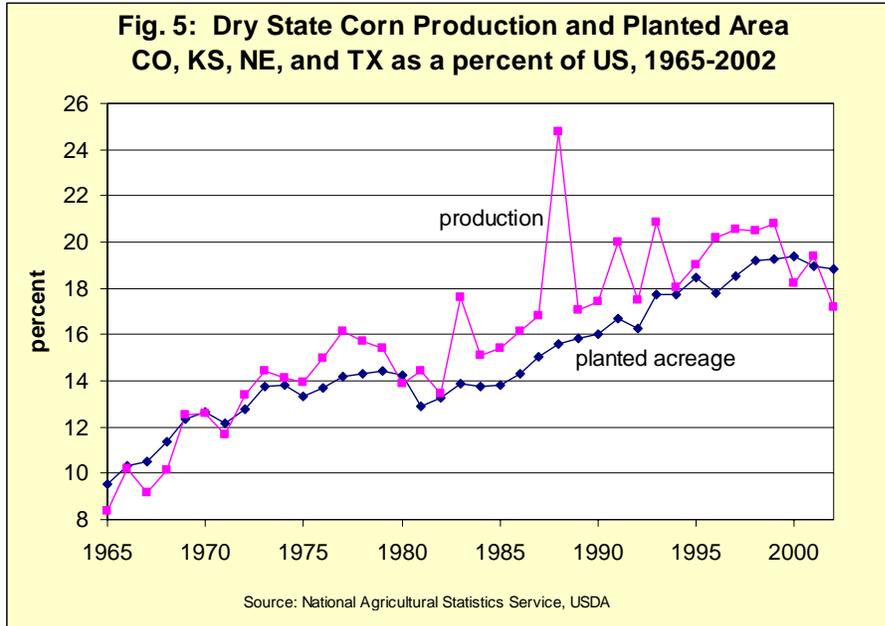
For insecticides, the apparent drop to under 40% of the volume/hectare turns out to be misleading, as the toxicity of insecticides has increased, allowing lower application quantities to deliver the equivalent chemical intensities. The apparent dramatic decline in insecticide intensity in US corn production raises hopes that another technological innovation – the introduction of GM corn – may have resulted in some environmental benefits. The data, however, are misleading. The toxicity of leading pesticides has increased significantly over time, allowing farmers to apply lower volumes to deliver the same active ingredients. The apparent decline is largely the result of this rising toxicity. Alternative measures of insecticide use, such as number of acre-treatments, suggest that insecticide use has remained roughly the same or even risen slightly. Several studies suggest that the introduction of GM corn, in particular Bt corn engineered to control the European corn borer, has not produced the insecticide reductions seen for some other GM crops (Clark 1999; Heimlich, Fernandez-Cornejo et al. 2000; Benbrook 2001c).

Irrigation

Many parts of the United States, including most of the leading corn states, have ample rainfall for production of crops such as corn. However, agriculture has also expanded into dry areas where irrigation is necessary. Well-publicized problems concerning irrigation include the unsustainable rate of withdrawals from the Ogallala Aquifer, and conflicts over the scarce and overused water from western rivers. A significant fraction of corn is grown in areas facing these problems (NRC 1996; Opie 2000).

The 1997 Census of Agriculture found that 15% of corn (measured by harvested area) is irrigated. More than three-fourths of the irrigated corn is located in four states: Nebraska, Kansas, Texas, and Colorado. In these four states, 60% of all corn is irrigated; in the rest of the country, the proportion is less than 5%. All four of the irrigation-intensive states are located over the Ogallala Aquifer.

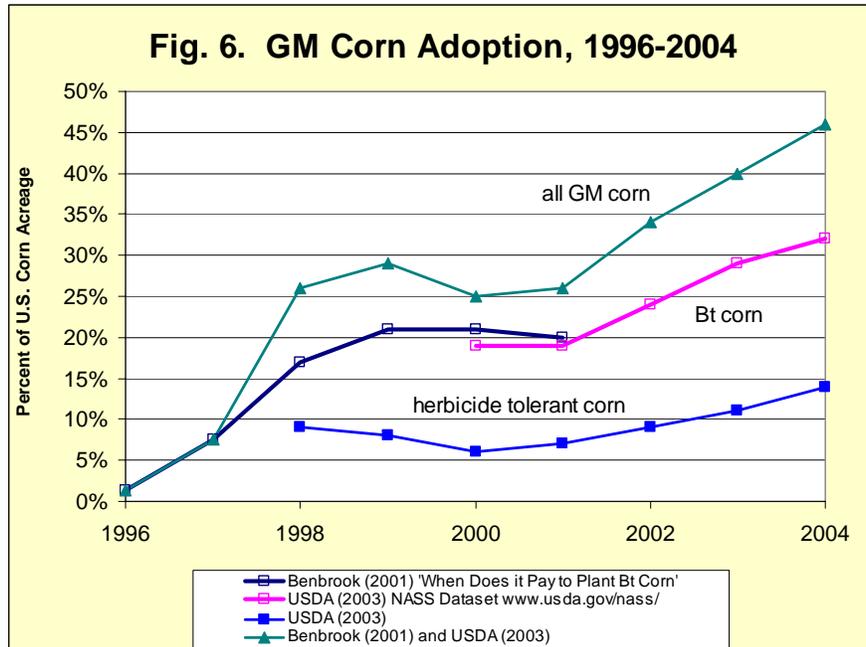
The 1992 Agricultural Census showed 13.9% of corn acreage was irrigated, implying a gradual rise in irrigation through the mid-1990s. (Data from the 2002 Agricultural Census is due to be available in late 2004.) To estimate changes in the NAFTA period, we can use planted area in the four “irrigation states” as a good proxy for the extent of irrigation. As Figure 5 shows, between 1993 and 1998 there was an increase in the share of US corn planted in these four states, from about 16% to about 19%. (Production figures have fluctuated more widely, mainly due to climatic conditions.) Though the dry-state share leveled off at about 19%, the increase is the most recent rise in an irregular but long-term trend toward increasing corn production in the drier states. In 1965, the proportion was only 9%.



As we will see in the next section, the rising share of dry-state production may be associated not only with unsustainable water use, particularly from the Ogallala, but also higher rates of insecticide use and Bt corn adoption, since the corn borer thrives in warmer, drier climates.

Genetically modified corn

The most widely discussed recent change in US corn production is the introduction of genetically modified (GM) corn, primarily Bt corn. This variety of corn contains genes from the soil bacterium *Bacillus Thuringiensis* (Bt) that produce toxins that kill certain insect pests, particularly the European corn borer and the Southwestern corn borer. Bt corn was developed in the 1980s, won its first regulatory approvals in 1992-93, and was first planted on a significant scale in 1996. It rose from 1.4% of planted area in 1996 to 32% in 2002. The other type of genetically modified corn widely in use is engineered to tolerate particular herbicides. Such herbicide-tolerant corn came into common use in 1998 and has grown from about 8% of US corn acreage to about 14%. As Figure 6 shows, despite a brief slowing of adoption rates between 1999 and 2001, US corn farmers have continued to increase their use of GM corn varieties. By 2004, projections showed over 45% of the US corn crop planted in GM varieties.



The debate on the safety and environmental impacts of biotechnology is still heated and unresolved. Many academic researchers, environmentalists, and GM critics have raised concerns about the impact of Bt corn on other species, on biodiversity in general and, on human and animal health. In a study for the Henry A. Wallace Center, Ervin, Batie et al. (2000) suggest that the genes may be transferred into wild relatives, which would reduce biodiversity and create herbicide, insect or viral resistance in weeds. In addition, the Bt toxin may have adverse effects on non-target organisms like butterflies or beneficial insect populations that help control pests. Matt Rand at the National Environmental Trust warns that biotechnology may have many unintended consequences which include allergic reactions and plant toxicity. In addition, he cautions that Bt produced from corn may accumulate in the soil (unlike organic spraying of Bt) and that the use of Bt corn will create pesticide resistance, thereby reducing the effectiveness of Bt as an organic pesticide (Rand 2001).

These concerns suggest the need for a precautionary approach to the commercial introduction of GM crops. The European Union applies the precautionary principle (that crops must be proven safe before being approved), whereas the US Environmental Protection Agency has a much lower burden of proof, often approving new GM crops when limited information is known (Ervin, Batie et al. 2000).

International concerns about GM safety have affected US export markets for corn. As Figure 2, presented earlier, showed, exports to the European Union and South Korea have declined precipitously. The European Union is now enacting a strict labeling regime, replacing a de facto moratorium on GM imports. South Korea, shaken by evidence of Starlink in some imports, established a strict labeling requirement as well. Japan, by far the largest importer of US corn, reacted strongly to the Starlink incident as well. A negotiated testing program and a lax labeling regime – 5% GM content, as opposed to

0.9% in the EU – have prevented US exports to Japan from declining significantly (Vazquez 2003).

With the recent discovery in Mexico of Bt transgenes in traditional maize fields, this concern has recently come to the fore in Mexico as well. Initial draft chapters of a commissioned report by the North American Commission for Environmental Cooperation confirmed the contamination – assumed to have come from imported grain distributed as food in a government program in rural areas – and some of the potential risks to Mexican consumers, farmers, agricultural systems, and ecosystems. Several of the authors noted that field tests of GM maize have only been done in US conditions, increasing the risks of unknown adverse impacts. It was estimated that 30% of US corn exports to Mexico are GM crops. A public presentation of the draft report, in the state of Oaxaca where the initial contamination was discovered, provoked near unanimous calls for increased Mexican restrictions on GM imports. The commissioned report, with recommendations, is due out in June 2004 (NACEC 2004).

As noted earlier, the rise of Bt corn correlates with the continued expansion of corn production onto drier lands. The corn borer, which the Bt toxin is intended to fight, thrives in warmer, drier climates with longer growing seasons. Thus it is not surprising that the adoption of Bt corn has been higher west of the Mississippi, where the dry states are located, nor that production gains from Bt corn are higher in dry states. According to one study, Colorado and Texas, which together accounted for only 6% of Bt corn planting, showed 45% of the production gains in 1998 (Benbrook 2001a). If Bt technology is allowing corn production to move into more arid lands that require irrigation, then unsustainable water use would be an additional environmental concern, beyond the warnings about Bt corn's direct impacts.

Other environmental impacts: soil erosion and biodiversity

There are additional environmental impacts from US corn production that are worth noting even though we do not review them in detail in this study. Two areas of concern are soil erosion and biodiversity impacts. A more detailed analysis of these issues is presented in Runge (2002), which we draw on here.

Conversion to cropland has carried with it rising problems with soil erosion. Some historical studies suggest that conservation tillage practices have significantly reduced erosion rates since the 1930s. This would suggest that expanding corn production has little impact on soil erosion rates.

Biodiversity impacts are still of concern with expanded corn production. In sharp contrast to the situation in Mexico, biodiversity in the corn crop itself is long gone in the United States. Commercially distributed hybrid varieties have been the norm in US production for decades. In addition to the dangers of Bt contamination and rising pesticide resistance among insects, there is one other way in which US corn production can impact biodiversity within the US. The long-term expansion of cultivated area in the US has reduced the area of grasslands and wetlands, while the growth in average farm size has

cut down many field edges that have been important habitats for birds and other species (Runge 2002). While proponents of biotechnology argue that increased yields from transgenic crops would reduce the need for cultivated land, this is an oversimplification: higher yields will not automatically lead to the return of existing cropland to wild habitat (Batie and Ervin 2001).

The role of US agricultural policies

Before moving on to discuss the environmental impacts in Mexico, it is important to note the importance of recent changes in US agricultural policies. There has been a great deal of attention paid to the increases in domestic farm subsidies following the 1996 Freedom to Farm Act. Corn is one of the most heavily subsidized crops in the United States, with subsidies accounting for some 46% of farm income in the sector. The 2002 US Farm Bill increased legislated levels of support, but because the increases only formalized emergency payments that had been made in recent years the actual increase was insignificant. The 1996 bill, though, represented a dramatic shift, moving US policy away from its historical reliance on supply-management mechanisms and toward direct subsidies. The change brought large areas of US agricultural land back into production and contributed to significant drops in producer prices due to oversupply (Ray, de la Torre Ugarte et al. 2003).

There is an extensive literature on the environmental impacts of farm subsidies, which is too detailed to address here. For the purposes of this study, we will only note that the OECD has developed a methodology to identify the most environmentally harmful subsidies (Porter 2002). There is significant debate about the validity of the distinctions drawn between, for example, domestic support decoupled from production and price supports in the form of deficiency payments. But there is consensus that with the exception of explicit conservation programs high levels of support for US corn production have significant negative environmental impacts by encouraging either the extensification or the intensification of production.

In terms of the impacts on exports, there is significant debate about the extent to which those high subsidy levels are the cause of low producer prices or their result (see, for example, Ray, de la Torre Ugarte et al. 2003). But there is little debate that US corn prices have been very low. This contributes directly to the economic pressures on Mexican maize farmers, since low US prices translate into low export prices. One recent study used US government data on costs of production and calculated that US corn in recent years has been exported at 20-33% below the costs of production (Ritchie, Murphy et al. 2003). The authors cite broader US farm policies and the political and economic influence of oligopolies in international grain trade, not domestic farm subsidies, as the primary cause of this alleged “agricultural dumping.” Whatever the cause, the lowering of commodity prices contributes to the economic impacts in countries such as Mexico, which import large quantities of US grain.

Environmental Impacts in Mexico

The impacts of Mexico's increased corn imports have been extensively studied by Nadal, in an earlier report for NACEC (Nadal 1999), a related later study (Nadal 2000), and a follow-up paper for NACEC (Nadal 2002). We do not attempt here to summarize this work, and the extensive work on the topic carried out by other researchers. Rather, we present an overview of the main environmental impacts of shifting maize production, followed by a more detailed discussion of the ongoing debate over the extent to which these changes threaten Mexico's rich diversity in maize and its wild relatives.

As noted earlier, at an economic level Mexico has experienced the flip side of the growth experienced in the United States. Consumption continued to grow after 1994, fueled in part by the elimination of Mexico's longstanding ban on feeding corn to livestock. But the increases were supplied by imports, more than 99% of which come from the US. Real producer prices fell 48% with the doubling of imported maize from the United States. Those real price declines have now reached 70%. These changes were experienced quite differently by the different types of Mexican producers.

Where US production is virtually all based on intensive industrial farming methods, Mexico's maize-producing sector is more diverse, with a small but significant number of modern growers, geographically concentrated in Sonora and Sinaloa, and a large number of small and medium-sized producers using more traditional methods. The economic and environmental impacts have been quite different for these different groups. In this paper, we will focus more on the impact on traditional producers, as the most important environmental impact of NAFTA-induced trade in maize is the threat to agrobiodiversity.

Due to price incentives and other market distortions that temporarily favored maize and bean production, modern producers in Sonora and Sinaloa dramatically increased production in the mid-1990s. With the removal of price supports, production in Sonora has since fallen to below its 1990 levels; in fact, irrigated land planted in maize dropped 40% nationally between 1989 and 2001 (de Ita Rubio 2003). There was a decline in acreage in Sinaloa as well, but a tripling of yields have allowed production in Sinaloa to rise to ten times its pre-NAFTA level (SIACON 2003).

In a detailed case study for NACEC, de Ita (2003) assessed the environmental impacts of expanding industrial maize production in Sinaloa. Not surprisingly, the impacts mirror those in the United States: high chemical use, with its accompanying environmental impacts; unsustainable water use for heavily irrigated farms. GM maize cultivation is still banned in Mexico, so potential damage from Bt maize is not present in Sinaloa at this time.

While Sinaloa's share of national production increased dramatically during the 1990s, production in more traditional sectors of Mexico's maize economy have stagnated or declined. These producers vary greatly in the extent to which they employ modern industrial farming methods or interact with the commercial market. Chemical fertilizer

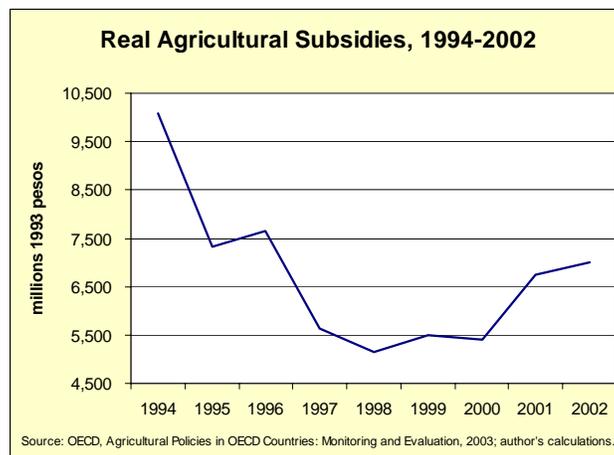
use is fairly common, but traction, irrigation, and pesticide use are not as widespread. Neither is the use of improved seeds. In terms of integration with the commercial market, according to one recent study, one-third of Mexico's small corn farmers are self-sufficient, that is they do not buy or sell significant quantities of corn. Another 28% are net consumers, selling in surplus years but overall buying more than they sell. The remaining 40 percent are net sellers, so they are the most harmed by lower prices coming from imports. This segment accounts for the majority of corn harvested in the country (ERI Consultants 2001, 13).

Mexican Agricultural Policy: A Pattern of Disinvestment

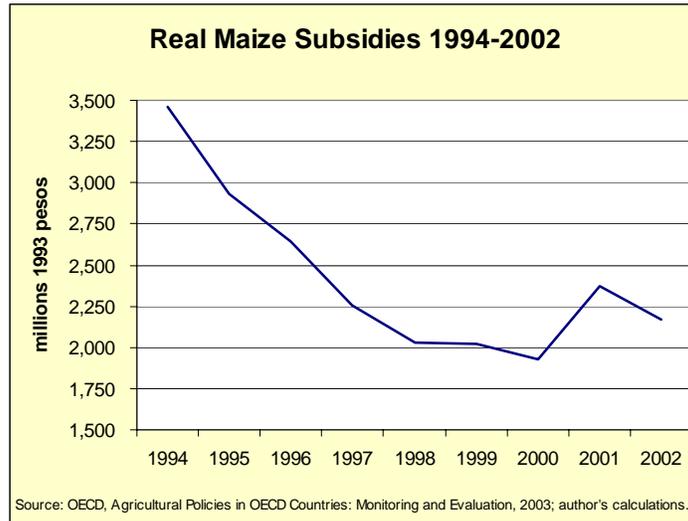
Before assessing the environmental impacts in this sector, it is worth reviewing briefly some of the dramatic changes in Mexican agricultural policies. While most of these changes were not mandated by NAFTA, they clearly form part of the larger economic reform program of which the agreement is a part. In addition to the decision not to enforce the TRQs for maize and other agricultural imports, the Mexican government also removed price supports, dismantling CONASUPO, the state trading agency that had managed all aspects of maize support for small producers. CONASUPO ceased to exist in 1999, but its scope and influence were reduced significantly in maize in previous years. The government also eliminated its program of subsidized credit through the government's Banrural in 1992. Finally, there was a revision of the constitutional constraints on land tenure, carried out in the restructuring of the laws regulating *ejidos* and communal lands. These changes allowed for the private sale of some collectively held agricultural lands (Appendini 2001).

The result has been severe pressure on the agriculture sector as a whole, but particularly those producers growing for subsistence of for the domestic market. The following figures tell the story.

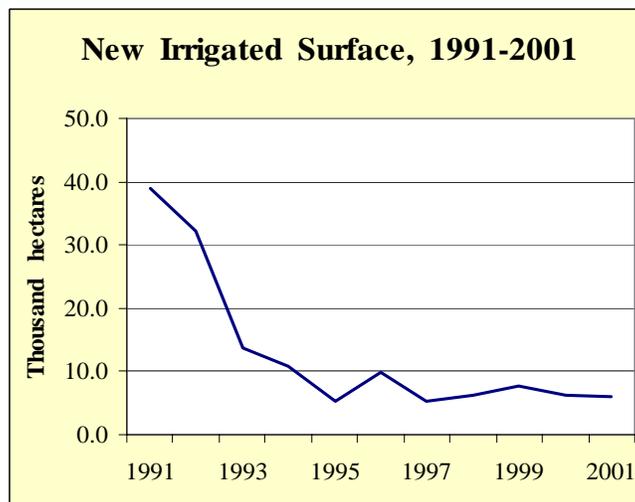
Real agricultural subsidies have declined dramatically, hastened by the 1995 peso crisis, which cut government revenues. As the graph shows, Mexican support programs for the agricultural sector as a whole dropped nearly 50% and had recovered to only about 70% by 2002.



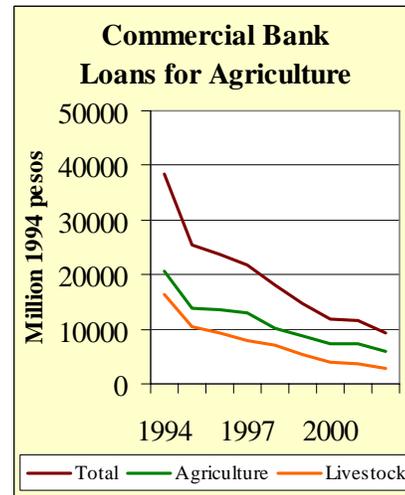
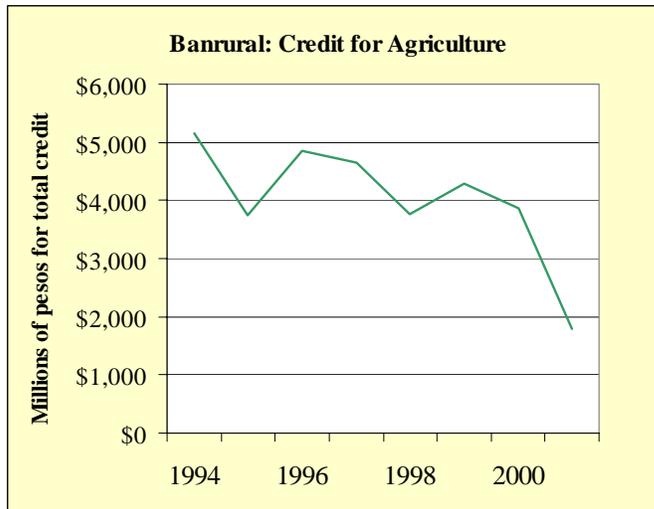
This decline in government support is mirrored for maize producers as a whole, with real declines of nearly 50%. There has also been an important restructuring of support programs to incentivize modern export-oriented production. So small-scale maize producers have experienced declines in government support even more dramatic than these figures would indicate.



The government has also reduced its investment in the one technological improvement that would most increase agricultural productivity – irrigation. Since the early 1990s, new irrigated surface has dropped from about 40,000 hectares a year to about 7,000. What investment there has been has gone into the more modernized sectors of agriculture, particularly those oriented toward exports. By historical standards, investment levels in agriculture are remarkably low. In 1980, investment was 11 percent of agricultural GDP. By 1985 it was down to six percent, which was where it stabilized briefly from 1989-92. In 1993, however, it dropped to 3 percent, and it has not surpassed 2 percent since (ERI Consultants 2001, 20-21).



The other area in which support has dropped precipitously is rural credit. Since NAFTA the government program for rural credit, Banrural, showed a dramatic decline in credit programs. Commercial banks did not step in to make up the shortfall. In fact, quite the opposite happened, with total commercial credit for agriculture declining precipitously since 1994 to about one-quarter its previous level. While the peso crisis caused the sharpest drops, the decline has continued since.



(Source: Nadal 2002)

It is also worth noting that Mexico's decision to rely heavily on foreign direct investment for its economic development has not benefited agriculture. While the country has seen dramatic increases in FDI, particularly from the US, only 0.3% of the remarkable \$128 billion that has flowed into the country since NAFTA has gone into agriculture.

Table 2.

US Foreign Investment in Mexico, 1999-2002		
Total US FDI		\$44,000,000,000
In agriculture	0.4%	\$172,000,000
Hog farming	69%	\$120,000,000
Horticulture, flowers	26%	\$45,000,000
All others	5%	\$7,000,000
Coffee	.000025%	\$4,300
Sinaloa, Sonora	89%	\$154,000,000
All other states	11%	\$18,000,000
Oaxaca	.00003%	\$5,400

A closer look at the distribution within agriculture for the 1999-2002 period shows that traditional sectors have, not surprisingly, received little in the way of foreign investment. In that period, of the \$44 billion in FDI, only \$172 million (0.4%) went to agriculture. Of that total, 95% went into hog farming, horticulture, and flower cultivation, with only \$7 million going into other areas. FDI was geographically skewed as well, with 89% of agricultural FDI going to Sinaloa and Sonora, the more modern agricultural states. By contrast, Oaxaca, one of Mexico's most traditional and poor agricultural states, saw only \$5,400 in FDI in this recent four-year period.

Environmental Impacts in Traditional Maize Production

Traditional cultivation practices, evolved over centuries of corn growing, involve the use and preservation of many natural varieties (landraces) of corn that are adapted to varying local conditions. It is this traditional style of production that preserves the genetic diversity of Mexican maize in practice. This diversity is of importance not just in Mexico but for the world's crop breeders, who rely on this genetic pool in the development of new varieties that can adapt to changing conditions. Threats to traditional cultivation and its living repository of biodiversity come in two distinct, widely discussed forms: the contamination of traditional fields by GM maize and economic pressures that lead to an abandonment of traditional farming and a resulting loss of important landraces.

The contamination issue has been taken up by NACEC in a commissioned study that is due out in June 2004, and it was the subject of a spirited public hearing in March 2004 in Oaxaca, where the contamination was first discovered. Several draft chapters of the report, which were made public prior to the hearing, highlight the uncertainty of the science of gene flow and the wide variety of potential risks to Mexico's ecosystems, agricultural practices, and communities and cultures. The scientific consensus in the new papers was that a precautionary approach was warranted. The current levels of contamination, which are presumed to have come from farmers experimenting with imported grains distributed through the government food program, DICONSA, may not pose a significant threat to Mexico's agro-biodiversity. But it is difficult to know for certain since the only field testing has been done in the US, so not under conditions found in Mexico, and only in the short term. The tone of public participation was strident, urging the advisory group to recognize local farmers rights to choose to keep their fields free of transgenes and to impose more severe restrictions on the GM imports and distribution (NACEC 2004).

Market Pressures and Biodiversity

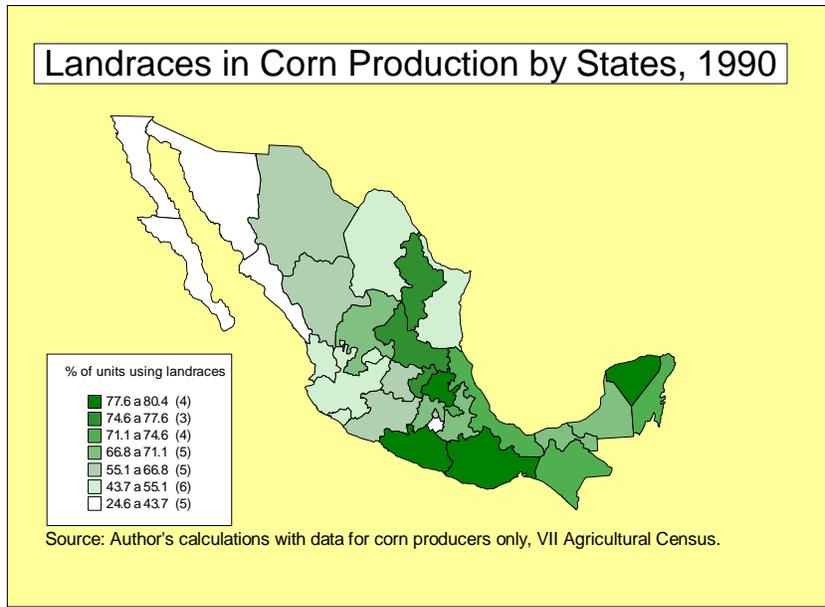
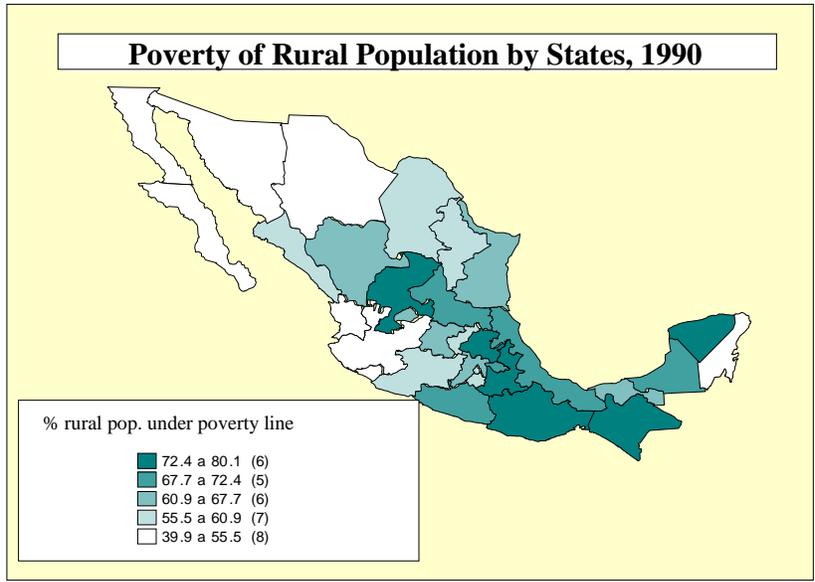
This potential mechanism of literal genetic contamination is an important warning about the implications of Bt corn consumption, and the uncertainty that still surrounds the very new technology of genetic modification of crops. Less dramatic, but probably more serious, are market pressures that reduce the extent of traditional cultivation, either through out-migration of farmers with traditional farming knowledge and experience, or through displacement of traditional corn varieties with other crops or with commercial hybrid seeds. It is now a subject of intense research to determine the extent to which this

shift away from genetically diverse corn production is taking place. Has the combination of market liberalization, increased imports and lower prices undermined the use and preservation of traditional seed varieties?

Research on this subject is not as straightforward as one might expect, for several reasons. First, the Mexican government failed to carry out its scheduled once-a-decade agricultural census in 2001. This would have been the source for some useful longitudinal comparisons of agricultural practices, including landrace use, by subgroups of producers. In the absence of this data, we are left to infer a great deal from other data, such as on production or planted area. Second, and related to this problem, data is often either too aggregated to be conclusive or too localized to allow for broad generalizations. State-level data masks many different agricultural practices, while community-level studies can only be indicative of larger trends.

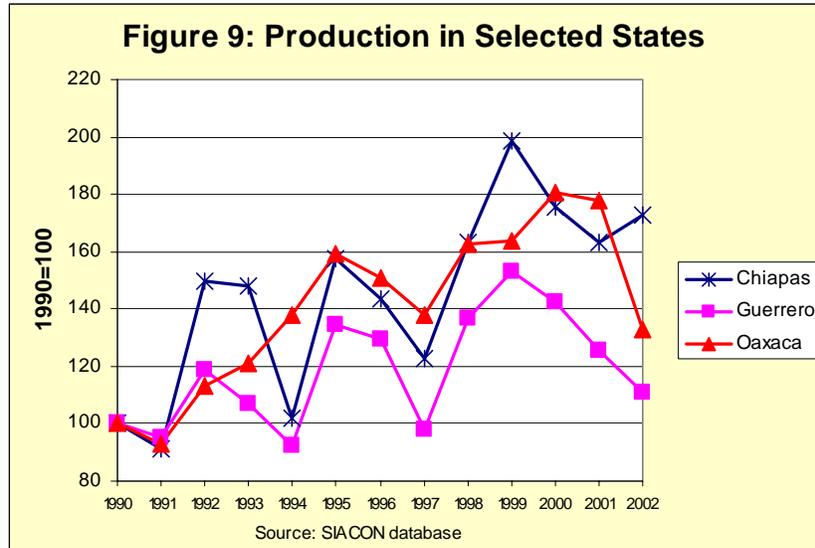
Finally, the threats to agro-biodiversity are long-term in nature. To the extent they reside in the migration patterns of traditional farmers, we know that families do not generally abandon the land en masse but rather export labor, generally younger members, over time, sustaining the homestead with remittances from migrant family members. Given the legal rights associated with maintaining an active farm, there is an incentive to keep the land planted by keeping some family members at home. Thus, figures on production or planted area or even migration may mask trends that are leading to the gradual loss of traditional knowledge in the process of seed selection, which is the basis for the ongoing evolution and stewardship of maize genetic diversity.

What is clear is the overall relationship between poverty and the use of traditional maize landraces. As the following maps from 1990 show, the map of rural poverty closely mirrors the map of genetic diversity. This is not surprising. Traditional agricultural practices tend to prevail in more marginal environments, where native landraces have been selected over the generations to provide unique advantages not available in high-yield hybrid seeds. The map of cultural diversity would also show similar shadings, as indigenous farmers concentrated in the southeastern section of the country tend to use the widest diversity of seeds while also suffering the highest levels of poverty and marginalization.

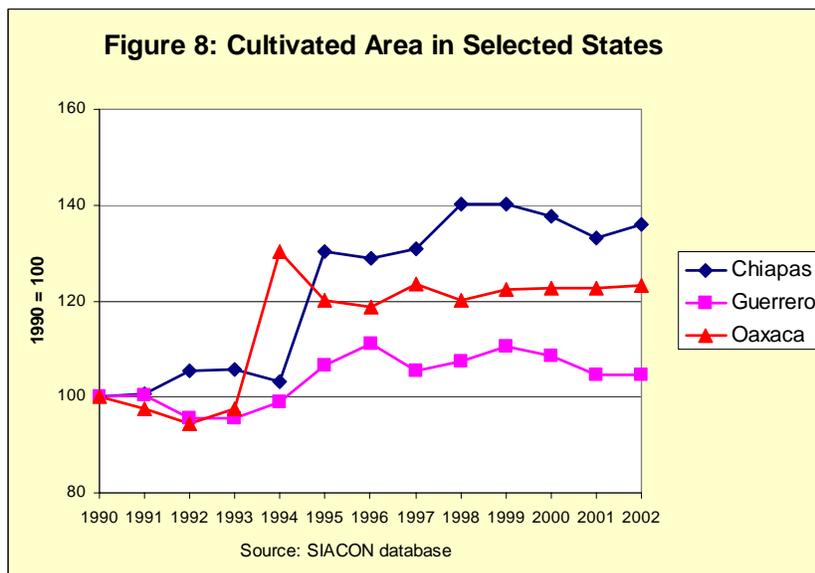


(Source for both maps, Nadal 2000)

Annual data are available on cultivated area and production by state. The southeastern states of Oaxaca, Guerrero, and Chiapas tend to be dominated by traditional production methods. Less than one-quarter of producers use improved varieties, far fewer employ tractors, and less than 2% of the area was irrigated (from 1991 Agricultural Census via Nadal 1999). While there are significant pockets of modern industrial agriculture in these three states – particularly in Chiapas – they can give a useful initial indication of the overall trends.



As the two graphs show, these states have seen increases since 1990 in both maize production and planted area. Setting 1990 to 100 for comparison purposes, we can see that with seasonal variations production rose in all three states through 2002. While the growth was strong and sustained in Chiapas, ending the period 70% higher than 1990, in Oaxaca and Guerrero the growth was neither as strong nor as sustained, ending the period up 30% and 10% respectively. Cultivated area, perhaps a more useful indicator of the extent of landrace use over time, showed increases of 5%-35%, with Chiapas again demonstrating stronger growth.



Both findings are significant in that they seem to confirm a widely observed phenomenon: that the predicted rapid exodus of traditional maize farmers following NAFTA's liberalization and the resulting price decreases may not have taken place. While there is a consensus that economic conditions have not produced the wholesale

abandonment of traditional maize farming, there is intense debate about what this means – for the livelihoods of corn farmers, the hoped-for modernization of Mexican agriculture, and the long-term future of the country’s maize diversity.

Nadal (2000) notes that prices for other traditional crops suffered declines similar to or greater than that of corn, making a shift to other crops less viable. Pointing to evidence of expanding cultivation and declining yields in some traditional areas, he attributes the apparent persistence of traditional corn production to survival strategies of peasant farmers, who bring more marginal lands under cultivation in order to grow for subsistence. Yúnez-Naude and Barceinas Paredes (2003) suggest that a significant proportion of corn farmers grow for subsistence and are likely to remain isolated from market forces, reducing the impact of falling prices and decreasing the threat to maize genetic diversity. However, Taylor and Dyer (2003) found that there has indeed been a significant increase in rural migration to the United States since the mid-1980s, and that trend has been particularly rapid since NAFTA took effect, showing an increase of 175% from 1994 to 2002. It is difficult to believe that such large-scale migratory trends will not eventually translate into losses in maize production, local knowledge, and maize diversity.

New Data on Migration

New research at El Colegio de Mexico suggests that it is indeed premature to conclude that depressed producer prices do not threaten genetic diversity in maize. To examine more disaggregated data than previous state-level analyses have used, we used the government-generated “Rural Development Districts” (DDRs, by their Spanish acronym). Created to facilitate the delivery of government support programs, DDRs are more integral agricultural units that tend to share economic and ecological characteristics. By mapping data from Mexico’s 2,531 *municipios* into the 192 DDRs for information on social marginalization, migratory flows, intensity of use of local landraces, changes in cultivated and harvested land, as well as output, and the evolution of rural prices, we can assess the extent to which economic pressures are threatening the diversity of Mexico’s more diverse farms.

Table 3 presents our initial data analysis. We divided the nation’s DDRs into five categories based on their intensity of landrace use. Based on this degree of diversity, we assessed poverty levels for 1990 and 2000; international migration for 1995-2000; internal migration rates within Mexico; and changes in planted area, crop failure, and output.

The data confirms several prevailing findings and challenges others. They confirm the finding that those employing the greatest diversity of native seeds suffer the highest levels of poverty, and this has remained true over the decade. Our data also confirm that the poorer and more diverse maize farmers have expanded the area planted in maize since 1990, by 26% and 33% for the highest and second highest fifths of maize farmers in terms of diversity. Output has increased as well, though susceptibility to crop failure remains highest for these two groups, suggesting that they are bringing more marginal land under cultivation in order to cope with rising economic pressures. Also consistent

with previous analysis is our finding that international migration remains most intense not for the poorest, most diverse producers but for those showing relatively low diversity and slightly lower poverty rates. This confirms longstanding observations that the costs of international migration make it a difficult option for the poorest rural families.

The data challenges one widely held view of the impact of declining maize prices and government support programs on the most diverse farms. Internal migration is common for poorer producers, who include those using a diversity of landraces. In fact, the two-fifths of DDRs that show the highest levels of seed diversity – nearly two million producers representing 68% of Mexico’s maize growers – have seen net out-migration for migratory patterns within Mexico. Those areas of moderate diversity have seen a balance between incoming and outgoing internal migrants, while the least diverse DDRs have been net attractors of internal migrants. A closer look at the data suggests that internal migration is often an intermediate step in the process of international migration. Poor farmers may well be migrating to the horticulture fields initially, then moving on to the United States when they earn enough to afford the trip.

Table 3. Maize Diversity, Poverty and Migration, 1990-2000

Level of Diversity 1990	Number of Producers 1990	% of total producers 1990	% Incomes Below Five Minimum Wages, 2000	Index of Int. Migration, 1995-2000	Internal Migration Rate 1995-2000 (per thou)	Change in cultivated area, 1990-2000	Change in unharvested area, 1990-2000	Change in production, 1990-2000
Very high	684,147	25%	81.50	low	-4.80	26.1%	39.6%	12.7%
High	1,157,916	43%	72.40	medium	-2.16	32.6%	32.4%	41.9%
Medium	651,524	24%	74.50	low	-1.50	14.6%	25.1%	12.2%
Low	158,476	6%	72.40	high	-0.96	24.5%	1.6%	33.2%
Very Low	62,374	2%	69.74	low	9.22	2.4%	1.2%	0.1%

Sources: VIII Censo Agrícola, 1991; Sagar/SIACON database; CONAPO.

These data require more extensive analysis to examine the links between falling producer prices, rural poverty, migration, and the long-term maintenance of Mexico’s stock of agro-biodiversity. These initial findings should serve as a warning to those who would conclude that agro-biodiversity in maize is secure. The long-term expulsion of family members from the households of those farming the most diverse varieties of maize is likely to interrupt the transmission of local knowledge, undermining the seed selection upon which agro-biodiversity depends. By all accounts, stagnation or decline in Mexican agriculture and in other sectors of the Mexican economy has limited the options available to farmers suffering the effects of low maize prices. This may have slowed the feared exodus from traditional maize, but it may not have prevented it. Paradoxically, things could get worse for agro-biodiversity if things get better for the Mexican economy. Better opportunities elsewhere – in agriculture, in the Mexican service sector, in the United States – could offer traditional maize farmers viable alternatives to producing for subsistence or selling maize in the market at the prevailing low prices.



Finally, it is worth noting that other market distortions have prevented the drop in producer prices from translating into significant benefits to the consumer. Tortilla prices are now about one-third higher than they were at NAFTA's passage, despite the 47% drop in real producer prices. This imperfect price transmission is due to oligopoly market structures in the corn flour industry, where two firms control 97% of the commercial market (Nadal 2000). This level of concentration is extreme, but such market distortions are commonplace in international agricultural trade and should be examined, along with environmental externalities, for their impacts on expanding trade in agricultural products.

Conclusions

We began with an analytical framework that recognized the possibility that the flow of environmentally unsustainable economic activity in the case of increasing agricultural trade could be from South to North, with net environmental costs for the trading partners as a group. This has been clearly demonstrated in the case of maize trade between the US and Mexico. More sustainable agricultural practices in Mexico, most notably the preservation of maize genetic diversity but also less chemical-intensive production, are threatened by competition from more environmentally damaging production methods in the United States.

Applying the concept of the globalization of market failure, we located this market-based competition within an analysis of the positive and negative environmental externalities associated with Mexican and US production methods respectively. As the study shows, Mexico's low-yield, traditional maize farmers go uncompensated for their long-term stewardship of genetic diversity in this important world food crop. Meanwhile, US producers do not have to internalize the environmental costs of their chemical-intensive industrial farming. Moreover, US producers are actually the indirect beneficiaries of Mexican farmers' stewardship, since their high-yield hybrids are derived from the varieties that originated in Mexico's fields. The controversy over contamination of

traditional fields in Mexico with Bt transgenes from grains imported from the US adds to the potential negative environmental impacts of liberalized trade in maize.

The result in the liberalized North American economy is competition that exacerbates the economic and environmental impacts of those distorted markets. Market failures in one area – negative externalities in the US – interact with market failures in another – positive externalities in Mexico – to create a net environmental impact that is greater than the sum of its parts.

To what extent can this analysis be extended to other crops, other countries, and other trade agreements? Looking at Latin America, there are clearly other crops and countries that share Mexico's status as a center of important genetic diversity for traded food crops. Potatoes in the Andean highlands would be a clear example. But positive environmental externalities are present in many traditional forms of agricultural production, from low chemical use to soil stabilizing farming techniques. Where traditional production continues to be a significant part of Latin American agriculture, it is important to assess the environmental benefits of such activities before throwing such producers into deregulated competition with their US and Canadian counterparts.

The case of Mexican maize clearly calls into the question the wisdom of across-the-board agricultural trade liberalization. While the Mexican government's unilateral abandonment of NAFTA's 15-year transition period to free trade in maize exacerbated the impact on Mexico's traditional maize farmers, there is no transition period that would address the problems with liberalizing a sector so fraught with market distortions. If maize diversity is a common global good that is worth preserving, and if the market is unlikely to internalize these benefits any time soon, then non-market mechanisms will be needed to shelter such sectors in the economic integration process. In the end, tariffs may prove the best way to protect environmentally valuable farm sectors.

From a more positive perspective, the Mexican case poses another interesting question of more general interest. As we saw, demand for maize in Mexico has risen with the increases in livestock farming and industrial uses of maize. This demand has been largely filled by imports from the United States. But would a different set of trade arrangements and government policies allow rising demand in Mexico to serve as the economic stimulus to improve the livelihoods and long-term economic prospects of traditional corn farmers? If so, one of the environmental costs of changing corn trade under NAFTA is the lost opportunity to secure Mexico's genetic wealth for our common future.

REFERENCES

- Ackerman, F., T. A. Wise, et al. (2003). Free Trade, Corn, and the Environment: Environmental Impacts of US-Mexico Corn Trade Under NAFTA. Trade and Environment in North America: Key Findings for Agriculture and Energy. North American Commission for Environmental Cooperation. Montreal, North American Commission for Environmental Cooperation.
- Anderson, W., R. Magleby, et al. (2000). Agricultural Resources and Environmental Indicators, 2000. Washington DC, U.S. Dept. of Agriculture, Economic Research Service, Resource Economics Division.
- Appendini, K. (2001). De la Milpa a los Tortibonos: La Reestructuración de la Política Alimentaria en México. Mexico City, El Colegio de México; Instituto de Investigaciones de las Naciones Unidas para el Desarrollo Social.
- Batie, S. S. and D. E. Ervin (2001). "Transgenic crops and the environment: missing markets and public roles." Environment and Development Economics 6(4): 435-457.
- Benbrook, C. M. (2001a). When does it pay to plant Bt corn? Farm level economic impacts of Bt corn, 1996-2001. Sandpoint, Idaho, Benbrook Consulting Services.
- Benbrook, C. M. (2001b). Factors Shaping Trends in Herbicide Use. Sandpoint, Idaho, Northwest Science and Environmental Policy Center.
- Benbrook, C. M. (2001c). Do GM Crops Mean Less Pesticide Use? Pesticide Outlook: 204-208.
- Boyce, J. K. (1999). The Globalization of Market Failure? International Trade and Sustainable Agriculture. Amherst, MA, Political Economy Research Institute (PERI).
- Brush, S. B. (2000). Genes in the Field: On-Farm Conservation of Crop Genetic Diversity. New York, Lewis Publishers.
- CIMMYT, I. M. a. W. I. C. (2001). Draft Consensus Document on the Biology of Zea mays subsp. mays (maize), OECD Program of Work on Harmonization of Regulatory Oversight in Biotechnology.
- Clark, E. A. (1999). Ten reasons why farmers should think twice before growing GE crops, E. Ann Clark, Plant Agriculture, University of Guelph. **2003**.
- Copeland, B. R. and M. S. Taylor (2003). Trade and the Environment: Theory and Evidence. Princeton, N.J., Princeton University Press.
- de Ita Rubio, A. (2003). Los Impactos Socioeconomicos y Ambientales de la Liberalización Comercial de los Granos Básicos en el Contexto del TLCAN: El Caso de Sinaloa. Mexico City, North American Commission for Environmental Cooperation.
- ERI Consultants (2001). Producción y Comercio Agropecuarios de México en el Marco del Tratado de Libre Comercio de América del Norte y su Impacto en el Desarrollo Rural. Mexico City, Cámara de Diputados, Comisión de Agricultura y Ganadería.
- ERS, U. E. R. S. (2001). State Fact Sheets, <http://www.ers.usda.gov/StateFacts/>.
- Ervin, D. E., S. S. Batie, et al. (2000). Transgenic crops: an environmental assessment. Washington DC, Henry A. Wallace Center for Agricultural & Environmental Policy at Winrock International: 81.

- FAOSTAT, F. a. A. O. o. t. U. S. s. d. (2001). Agriculture data, FAO. **2001**.
- FATUS (2003). Foreign Agricultural Trade of the United States - Database Search, U.S. Dept. of Agriculture - Economic Research Service. **2004**.
- FATUS, U. F. A. T. o. t. U. S. (2001). Foreign Agricultural Trade of the United States - Database Search, U.S. Dept. of Agriculture - Economic Research Service. **2001**.
- Heimlich, R. E., J. Fernandez-Cornejo, et al. (2000). "Genetically Engineered Crops: Has Adoption Reduced Pesticide Use?" Agricultural Outlook(August 2000).
- Morris, M. L. (1998). Overview of the world maize economy. In : Maize Seed Industries in Developing Countries., Lynne Rienner Publishers, Inc. and CIMMYT, Int.
- NACEC (1999). Assessing Environmental Effects of the North American Free Trade Agreement (NAFTA): An Analytic Framework (Phase II). Assessing Environmental Effects of the North American Free Trade Agreement (NAFTA). Montreal, Commission for Environmental Cooperation.
- NACEC (2004). Maize and Biodiversity: The Effects of Transgenic Maize in Mexico. Maize and Biodiversity Symposium, Oaxaca, Mexico, North American Commission for Environmental Cooperation.
- Nadal, A. (1999). Issue Study 1. Maize in Mexico: Some Environmental Implications of the North American Free Trade Agreement (NAFTA). Montreal, Commission for Environmental Cooperation: 65-182.
- Nadal, A. (2000). The Environmental & Social Impacts of Economic Liberalization on Corn Production in Mexico. Gland, Switzerland and Oxford, UK, WWF International and Oxfam GB: 1-113.
- Nadal, A. (2002). Corn in NAFTA: Eight Years After. Mexico, North American Commission for Environmental Cooperation.
- NASS, U. N. A. S. S. (2000). USDA-NASS Agricultural Statistics 2000, U.S. Dept. of Agriculture National Agriculture Statistics Service. **2001**.
- NRC, N. R. C. (1996). A New Era for Irrigation. Washington DC, National Academy Press.
- Opie, J. (2000). Ogallala: Water for a Dry Land. Lincoln, NE, University of Nebraska Press.
- Porter, G. (2002). Subsidies and the Environment: An Overview of the State of Knowledge. Workshop on Environmentally Harmful Subsidies. Paris, OECD.
- Porter, G. (2002). Subsidies and the Environment: An Overview of the State of Knowledge. OECD Workshop on Environmentally Harmful Subsidies. OECD. Paris, OECD.
- Rand, M. (2001). Crops Under Question: The EPA and Bt Crops, National Environmental Trust.
- Ray, D., D. de la Torre Ugarte, et al. (2003). Rethinking US Agricultural Policy: Changing Course to Secure Farmer Livelihoods Worldwide. Knoxville, Tenn., Agricultural Policy Analysis Center, University of Tennessee: 59.
- Ritchie, M., S. Murphy, et al. (2003). United States Dumping on World Agricultural Markets. Minneapolis, MN, Institute for Agriculture and Trade Policy.
- Runge, C. F. (2002). US Agricultural Policy in 2002: A Four Dimensional Disaster. Winnipeg, George Morris Centre.
- Serratos-Hernandez Juan Antonio, F. I. G., Julien Berthaud (2001). Producción de maíz, razas locales y distribución del teozintle en México: Elementos para un análisis

- GIS de flujo genético y valoración de Riesgos para la liberación de maíz transgénico., Campo Experimental Valle de Mexico, Instituto Nacional de Investigaciones Forestales Agrícolas y Pecuarias (INIFAP) , Centro de Biotecnología Aplicada Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT).
- SIACON (2003). SIACON database, SAGAR. **2004**.
- Taylor, E. and G. Dyer (2003). NAFTA, Trade, and Migration. Washington, D.C.
- Turrent-Fernandez, A. N. G.-M., J.L. Ramirez-Diaz, H. Mejia-Andrade, A. Ortega-Corona and M. Luna Flores (1997). Plan de investigación del sistema maíz-tortilla en los Estados Unidos Mexicanos, Internal Document, INIFAP-SAGAR.
- Vazquez (2003). Declining US Corn Exports: What is the GMO Factor?, GE Food Alert Campaign Center. **2003**.
- Wilkes, G., C. W. Yeatman, et al., Eds. (1981). Plant Genetic Resources: A conservation imperative. American Association for the Advancement of Science selected symposium. Boulder, Colorado, Westview Press.
- Wise, T. A. (2004). The Paradox of Agricultural Subsidies: Measurement Issues, Agricultural Dumping, and Policy Reform. Medford, Mass., Global Development and Environment Institute: 32.
- Yúnez-Naude, A. and F. Barceinas Paredes (2003). The Agricultural Sector of Mexico After Ten Years of NAFTA. Washington, D.C., Carnegie Endowment for International Peace.
- Zahniser, S. and J. Link (2002). Effects of North American Free Trade agreement on Agriculture and the Rural Economy. Washington, US Department of Agriculture.