Corn in NAFTA: Eight Years After

Alejandro Nadal
Science, Technology and Development Program
El Colegio de México

A Research Report prepared for the North American Commission for Environmental Cooperation
May 2002

The author wishes to thank Frank Ackerman for comments to an earlier draft. The help of Israel Macías, who assisted in processing data is gratefully acknowledged. All errors are, of course, the sole responsibility of the author.

Corn in NAFTA: Eight Years After

Alejandro Nadal
Science and Technology Program
El Colegio de México

Table of Contents

Corn in NAFTA Eight Years After

Alejandro Nadal
Science and Technology Program
El Colegio de México

Introduction

In 1999, corn production in Mexico absorbed more than 53% of total cultivated land. It also occupied more than 2.5 million individual producers. These corn growers work under highly differentiated conditions in terms of technology and resource endowment. Production conditions are marked by deep differences in soil characteristics, topography, general climate, rainfall patterns and evaporation coefficients. Differences also arise from diverse sources of biotic stress associated with fungi, bacteria, insects and nematods. The level of heterogeneity is associated to the extraordinary mosaic of agrological and ecosystem diversity existing in Mexico, which is in turn closely related to the country's geographical and physical characteristics.[1]

When the North American Free Trade Agreement (NAFTA) was drafted and negotiated in 1992-1993, Mexico's corn sector was included. This was perhaps one of the most important single components of the new trade agreement. Access to Mexico's basic grains market had been a longstanding project of U.S. growers. Average yields and subsidies in the United States made Mexico's producers appear as highly uncompetitive.

It was understood that the economic forces unleashed by trade liberalization (especially the important price reductions as a result of imports from the U.S.) would bring about an important reallocation of land, labor and capital. The reallocation of these productive resources used in corn production in Mexico would allow Mexico to tap its comparative advantages in agriculture, especially in fruit and horticultural production. As a result, subsidies for corn producers would become unnecessary, a major policy goal as explicitly recognized in the two major studies supporting the decision to include corn in NAFTA (Levy and van Wijnbergen 1995, 1992). A significant proportion of displaced producers would enter the national labor market and would be employed in sectors of higher productivity. The overall outcome would be a positive contribution to the trade balance and to Mexico's fiscal accounts.

---

[1] This extraordinary geographical and physical diversity explains why Mexico is the fourteenth largest country in the world in terms of total surface, but ranks third in biological diversity (Mittermeier 1988). Because of its topography and climate regions which include a Nearctic realm in the north and a Neotropical realm in the south, Mexico hosts a wide variety of species in both flora and fauna (Rzedowski 1981). Thus, with only 1.4% of the world's surface, Mexico is host to almost 12% of the total number of known species (Toledo and Ordóñez 1993). Endemism is very intense: for plants, the percentage of endemic species ranges between 44%-63%, and for vertebrate animals, this percentage is 30% (INE, 2000). It ranks second in total number of reptiles, and first in number of endemic species of reptiles. It holds fifth place in total species of mammals. Mexico occupies fifth place in the world with respect to total number of vascular plant species, with 30,000 species of plants, of which 21,600 are flowering plants (Rzedowski, 1993). It also ranks fourth in total number of amphibians. Finally, it is the only country where megadiversity coexists with a center of agricultural origin within the gene belt, the band that circles the world within the Tropics of Cancer and Capricorn (Ramamoorthy *et al* 1993).

On the social and environmental front, trade liberalization in corn would also bring about welfare gains for producers and consumers alike. Producers would reap the benefits of the productivity gains associated to the more efficient allocation of resources. Consumers would also gain from the lower prices of key consumer goods, and especially of the country's staple food, tortillas and various corn products.

The reallocation of productive resources would also lead to improvements in soil management and reduced pressure on marginal land, as well as cuts in deforestation rates. Other possible environmental effects on use of pesticides and water resources, were disregarded, but the general perception was that benefits would surpass any potential damages. A overshadowing assumption was that, in general, modern and more efficient technologies would be adopted and assimilated in Mexico's agricultural sector, and this would bring about beneficial effects in resource usage rates. An important caveat was that adequate investments in the form of public expenditures were required to turn this scenario into a reality.

The critical environmental dimension of genetic resources was completely ignored during the NAFTA negotiations. This is surprising because already the loss of genetic resources is a major environmental problem. But the surprise is even greater if we take into account Mexico's position as the center of origin and diversity of corn, and the critical role of corn's genetic variability in the production strategies of most growers in Mexico. Most agronomists, plant breeders and geneticists were acutely aware of the strategic importance of Mexico's corn genetic resources in future expansion of world output in this cereal. But their observations were not taken into account as trade negotiators plotted the future evolution of Mexico's corn sector and the fate of corn producers. The failure to take this into account reveals the existence of an important gap in the assessment of environmental impacts of trade agreements.

Two previous studies (Nadal 1999, 2000) examined several potential environmental impacts of corn in NAFTA. Those analyses identified potential effects in soil quality, water resources, pesticides and genetic resources. In this paper we concentrate on recent developments concerning the impact on corn genetic resources. There has been little or no research on soil management practices, water resources or the use of chemical inputs. One of the most important dimensions concerns soil erosion and the possible impact of corn cultivation. There are no comprehensive studies on this aspect of corn production, although there are some specific research monographs covering new aspects of minimum tillage practices and other vegetative technologies used for soil erosion control.[2] In contrast, there are new and important developments in the realm of corn genetic resources.

The linkages between a trade agreement, such as NAFTA, and a specific environmental dimension, are sometimes difficult to determine. Our point of view in this analysis is that trade liberalization is only one aspect of a more complex package of economic policies. In other terms, trade liberalization is but one of many components of a wider economic strategy which, for want of other more apt semantics, we will call the open economy model. Thus, other macroeconomic considerations regarding interest and exchange rates, credit and monetary policies, financial liberalization, general economic deregulation, privatization, as well as fiscal expenditures, must be taken into account in assessing the interplay of economic forces working

[2] Personnal communication, Dr. Antonio Turrent, INIFAP (January 7 2002).

on economic agents as the open economy model unfolds. From this vantage point, the impact of tariff reductions and quota elimination must be examined in conjunction with the effects of other accompanying economic policies. Without this type of analysis, the connection between environmental impacts and trade agreements becomes difficult to understand.

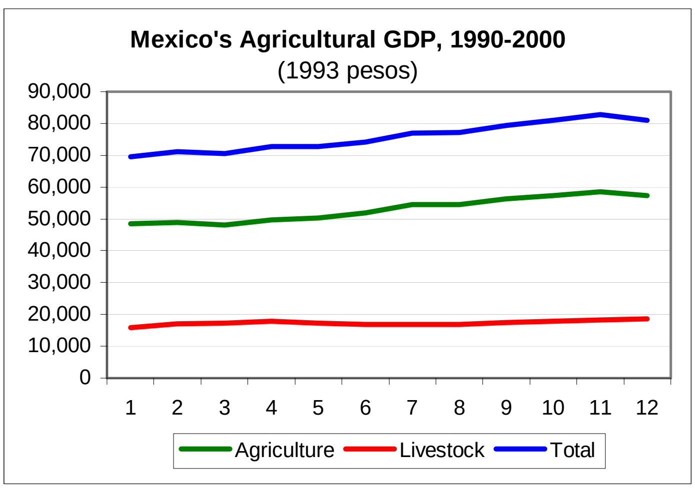
This paper's structure is as follows. In the first section we provide an overview of recent trends for Mexico's agricultural sector. This is the frame of reference for our more detailed analysis of the corn sector. The second section analyzes the implementation of NAFTA's corn regime. This analysis covers data on price dynamics, imports, the implementation of NAFTA's TRQ regime, and public expenditures. The third section focuses on the corn sector, examining trends in output, cultivated and harvested surface, yields and prices, both at the national and state levels. The fourth section examines poverty and social marginalization in Mexico's rural sector. The section includes a general overview of the relation between poverty and migration. The fifth section centers on the impact of NAFTA's corn regime on genetic resources. We include here an analysis of the impact of transgenic corn on Mexico's genetic resources. The final section focuses on policy recommendations.

I. RECENT ECONOMIC TRENDS IN MEXICO'S AGRICULTURAL SECTOR

I.1 Output, Cultivated Surface and Yields

Mexico's agricultural sector has remained in a state of stagnation during the past decade. The overall agricultural sector (including livestock output) increased by an average 1.6% per year, a rate inferior to total population growth. This is a rather unsatisfactory record for this sector.

Figure I



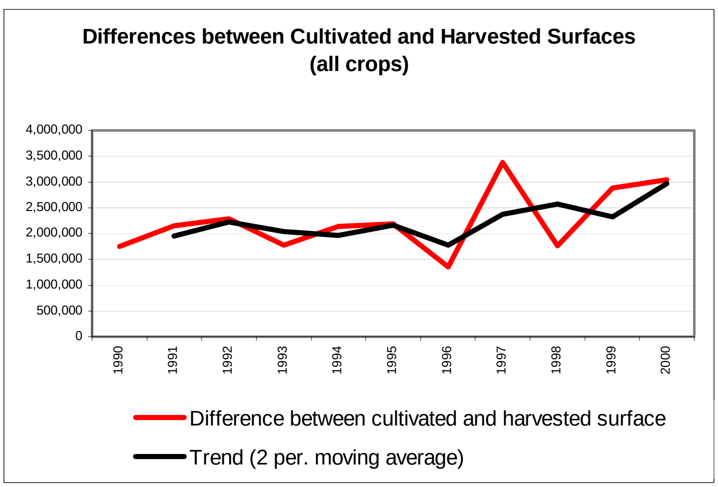
Source: SAGARPA.

This mediocre performance of Mexico's agricultural sector is accompanied by the expansion of total cultivated surface. This is a trend that marks the entire decade 1990-2000, as total cultivated surface expanded from 19.7 to 21.7 million hectares. This increment of two million hectares is explained basically by the expansion of land under rain fed conditions, not by the development of new land under irrigation (see data on infrastructure below).

Only one fourth of the new land under cultivation is dedicated to corn production, while all other crops explain three quarters of the newly cultivated land. Average yields have remained stagnant over the decade. For all crops, average yields in 1990 were 6.1 tons per hectare. Ten years later, yields reached 6.5 tons per hectare. In the case of corn, yields were 1.8 tons per hectare at the beginning of the decade, and by 2000 they had experienced a marginal increment and reached 2.0 tons per hectare. If the top corn producer in the nation (Sinaloa) is excluded, yields remain at their 1990 level. This overall performance for all crops, and especially for corn, is the result of a combination of causes, but lack of productivity augmenting investments probably bears the primary responsibility (we return to this point below).

The overall picture of Mexico's agricultural landscape suggests there is a moderate trend towards a more extensive pattern of cultivation, instead of bringing already cultivated land under more intensive methods of production. As cultivated surface expanded by 10%, yields only increased by 6.5%. This suggests there may have been an unfavorable impact on soils as land that is less suitable for agriculture was brought under cultivation. In addition, there is a disturbing trend in the difference between cultivated land and harvested land. The former involves economic costs in terms of tillage and inputs (both labor and fertilizers, which are frequently used by all classes of producers), while the latter corresponds to the land that effectively renders a harvest.

Figure II



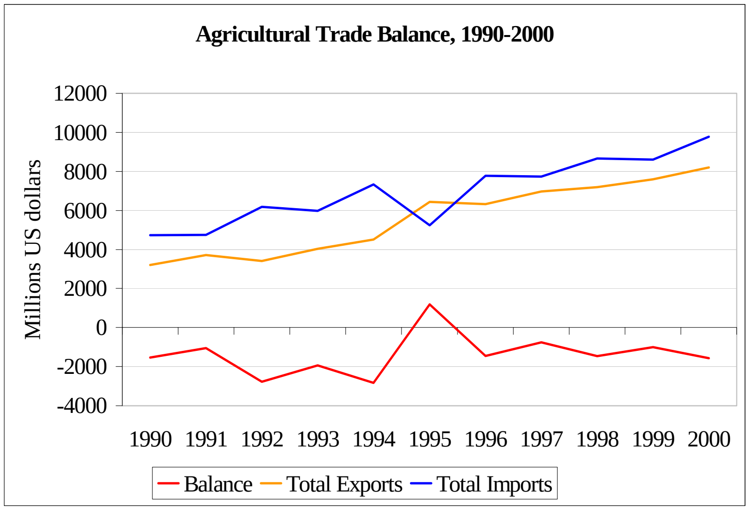
Source: SAGARPA

During the past decade, the difference between cultivated and harvested land doubled, from 1.5 million hectares to 3 million. Before 1996, the trend appears to be more homogeneous, indicating a more regular pattern of succession between good and bad years. After 1996, the process tends to become unstable. This increasing difference may be due to a higher coefficient of crop failure. Of course, agricultural performance is affected by many variables, and the coefficient of crop failure is a complex indicator embracing different types of factors. Higher crop failure coefficients may be due to climate factors, or deteriorating technology, but they can also be explained by bringing lesser quality land under cultivation. Our study cannot conclude that this is the determinant explanatory variable, but given the data on expansion of cultivated surface this cannot be ruled out.

I.2 Agriculture's Trade Balance

Mexico's agricultural trade balance has been running a deficit during the past decade. The deficit becomes even greater if we include agricultural (food) industries. Figure III reveals that

Figure III



Source: Secretaría de Economía.

the trade deficit disappeared during 1995, when the Mexican currency was significantly undervalued. However, the deficit returned swiftly the next year as the undervaluation became weaker. Corn trade makes a significant contribution to total imports and in 1996 they weighed heavily on the overall trade balance.

Exports of horticultural products increased dramatically, from 858 to 1,815 million dollars, and these exports became more diversified.[3] Yields in horticultural production increased at a swift pace, revealing important productivity gains. This is also reflected by the very modest growth in cultivated surface allocated to horticultural production: from 352 to 418 thousand hectares between 1990 and 2000. These productivity gains are good news, but the relatively unimportant increment in cultivated surface points out in the direction of small numbers of employment opportunities in this sector, a point to which we return below.

II. CORN IN NAFTA

II.1 NAFTA's Rules

The inclusion of corn in NAFTA was aimed at releasing productive resources that would find a more efficient allocation in other crops or sectors. But incorporating the corn sector in the free trade agreement constituted a delicate policy measure and Mexico's government chose to envelop the deal in a long-term transition period. The transition period would operate as follows: a tariff rate quota (TRQ) would immediately replace the old quota system, with a

[3] Tomatoes were responsible for nearly 50% of total horticultural exports at the beginning of the decade. In 2000 tomato exports were 26% of total horticultural exports.

fifteen year calendar to achieve complete phasing out of this TRQ.[4] The first year of implementation a 2.5 million ton tariff free import quota was granted by Mexico. By the year 2008, all corn imports would enjoy a zero tariff. This import quota was to grow at a 3% yearly rate and would lead to a tariff free quota of 3.5 million tons at the end of the fifteen year transition period. A tariff of 206.9% was set on imports above the tariff free quota for the first year of the agreement. This tariff would be phased out: during the first six years of the NAFTA the tariff would be reduced linearly by approximately 30%, while the remaining tariff was to be completely phased out during the other nine years.

The central variable in the fifteen-year transition period was the domestic price. In and by itself, the fifteen-year period would be meaningless without an adequate functioning of the corresponding price adjustment process. Price variations can of course be irregular and even volatile, but the TRQ mechanism is designed to provide stability to the adjustment process. For this to take place, the full tariff on imports above the tariff free quota must be exacted. We return to this point below.

Corn imports have increased from three million tons in 1993 to six million tons in 2001. The majority of total corn imports serves as inputs in processing industries producing feedstock for poultry and livestock (57% in 2001). Starch, oil and flour industries account for another 38% of total imports. These industries are the direct beneficiaries of the reduced price of corn imports and the fact that the tariff on imports exceeding the tariff-free quota have not been effectively levied, a point to which we return below.

Only 3% of imports is allocated to hominized corn flour (nixtamal) for tortillas. The state owned commercial firm DICONSA that distributes food at subsidized prices in poor rural and urban areas accounts 3% of imports. These corn imports distributed through the network of DICONSA stores in rural areas are basically used for direct human consumption, but some imported corn can find their way into Mexican corn fields as poor growers use it as seed.

Table I

Destination of Corn Imports by Industry				
	2000		**2001**	
Total Imports	6,122,622		5,314,026	
Feedstock	2,921,944	48%	3,017,463	57%
Starch industries	1,836,147	30%	1,397,293	26%
Corn flour industries	789,418	13%	489,744	9%
DICONSA	244,150	4%	169,207	3%
Dough and tortilla producers	227,000	4%	148,283	3%
Cereal industries	86,688	1%	73,979	1%
Fried pastries industry	17,275	0.3%	18,055	0.3%
NOTE: DICONSA See main text.				

Source: Secretaría de Economía.

Corn imports have exceeded the tariff free quota since the first year of the NAFTA's implementation. But Mexico's authorities have argued that the tariff has not been levied in order to ensure that tortilla prices would not increase. They also argue that effectively charging

[4] North American Free Trade Agreement (NAFTA) Annex 302.2 in Schedule for Mexico, tariff item 1005.90.99.

this tariff is a discretionary power conferred by NAFTA's text and not a obligatory act. Public officials even stated that if the tariff were charged, a special subsidy would have to be provided to industrial tortilla producers in order to keep tortilla prices down. This would, in effect, mean that what would be levied to these producers through the tariff would have to be returned through a special subsidy to those same agents. Unfortunately, this rationale was flawed.

During the period since the NAFTA came into force, tortilla prices have experienced a steep rise, with price increments surpassing 500% between 1993-2000. In addition, subsidies were provided to the producers of industrial tortilla, at least until 1998, when tortilla prices were completely deregulated. Thus, the lack of adequate implementation of the TRQ for corn was accompanied by the use of monopoly pricing power by industrial producers, canceling the consumer welfare gains that, in theory NAFTA would bring about.

The allocation of the import quota is determined by a special committee under the leadership of the Ministry of Agriculture (SAGARPA) and the Ministry of the Economy (ME). The main importers of corn sit in this committee: flour mills, industrial plants and oil refiners, high corn fructose producers, livestock and poultry producers. Mexico's corn growers have never been part of the committee. The lack of adequate representation of corn growers in the committee helps explain why the tariff on imports beyond the tariff-free quota has not been charged. This means that the main protection mechanism that was designed to define the terms of the transition period was never used.

Foregone fiscal revenues have exceeded (for the three crops with a TRQ regime in NAFTA) 3.5 billion dollars over the eight year period 1994-2001. In the case of corn, foregone fiscal revenues between 1994-1998 totaled 2.1 billion dollars.

Agricultural producers' associations have attempted to reverse this state of things. During the past five years, they have intervened during Congressional debates on the Federal budget. These associations and their allies in Congress secured a special article in the Federal Revenues Law for the year 2000 authorizing levying of a 30% ad valorem tax on corn imports exceeding the tariff-free quota established in NAFTA. However, government officials considered this article as giving them discretionary powers and decided not to exact this tax which would have provided more than 370 million dollars. The NAFTA tariff over the tariff-free quota for that year was 135%.

For the year 2001 the Federal Revenues Law included a peculiar obligation for the Executive: in the case that corn imports would exceed the tariff free quota, the level of the tariffs to be charged would be determined in consultation with producers' organizations. This time the law explicitly stated that a tariff would be levied on these imports. Although this ends the debate over discretionary powers to levy the tariff on corn imports, it maintains the confusion over the applicability of NAFTA's tariffs.

During the official visit to Beijing, a presidential decree was issued establishing a tariff of 1% on imports of yellow corn and 3% on imports of white corn exceeding NAFTA's taiff free import quota. During that year, the tariff established in the NAFTA's TRQ was 127%. Thus, the real tariff charged on corn imports over the tariff free quota remained a symbolic tax with no substantive effect on the evolution of domestic corn prices.

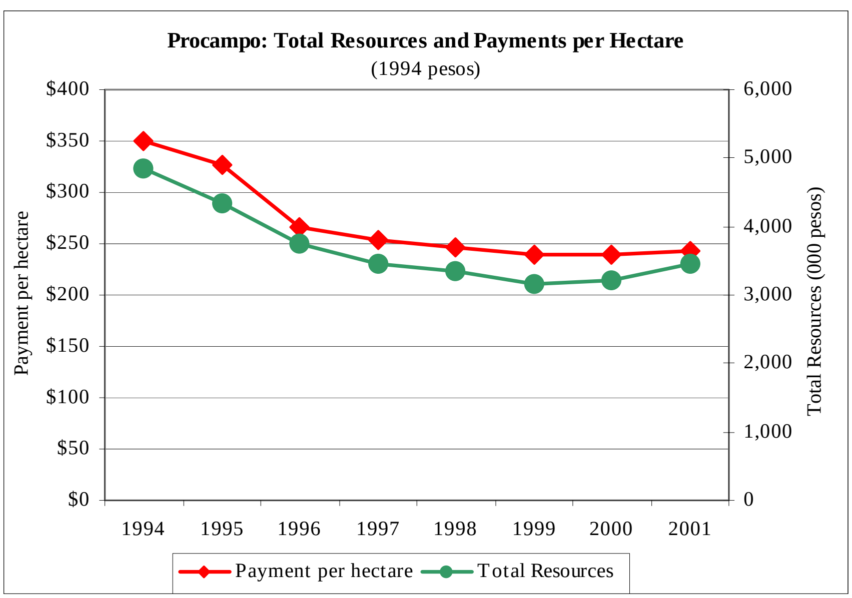
The tariff rate quota on corn, like all TRQ's, was not designed to stop imports. That is precisely the highly disruptive effect that is considered to arise from quotas and other quantitative barriers to trade. TRQ's are intended to reduce the impact of imports on prices. But if the tariff on imports over the tariff-free quota is not levied, there is a direct impact on prices as if the final year of the transition period had been reached. The impact of corn imports from the United States on domestic prices of corn in Mexico has been significant. The price of corn dropped from 1600 pesos per ton in 1993 to less than 800 in 1999. During that same period of time, *accumulated* inflation surpassed 150%. This means that real income for corn producers dropped steeply and at a very fast rate.

Mexican domestic corn prices have been aligned with international (mostly U.S. prices) since 1996. These international prices have been at a rather low level for several reasons. U.S. agricultural policies and the level of subsidies that have been allocated are probably the most important explanatory variable. Today, production costs of corn in the U.S. corn belt cannot be fully recovered by prevailing prices.

II.4 Investment in Agriculture

During this same period, public expenditures for the agricultural sector have maintained a steady downward trend. The most important policy instrument associated with trade liberalization in the corn sector is PROCAMPO, the income support mechanism designed to assist producers during the adjustment process brought about by trade liberalization. This income support mechanism has the advantage of not linking producers' decisions and technology and output with subsidies. This allows for a more efficient allocation of resources in response to market signals.

Figure IV



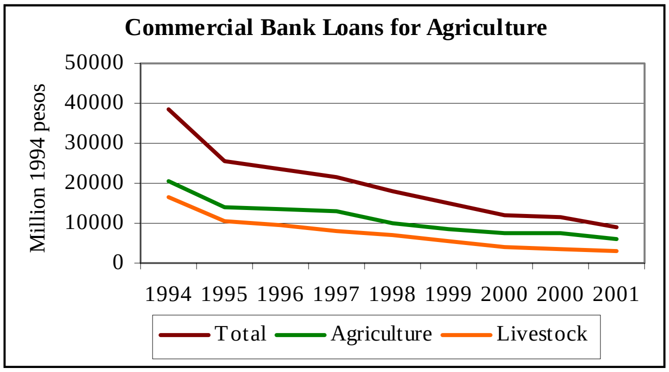
Source: Primer Informe de Gobierno, 2001.

Unfortunately, as can be seen in Figure IV, PROCAMPO has lost 30% of its value in real terms. Thus, this policy instrument has been unable to act as a counterweight to the loss of income brought about by the drop in corn prices.

Another important policy instrument is *Alianza para el Campo*, which comprises a series of loan mechanisms designed to aid producers in their modernization program. Through *Alianza* the government provides matching funds for producers that are willing to invest in new irrigation schemes or any other type of fixed investment. This program is geared towards producers with a higher degree of competitiveness. Again, this policy instrument was to be a key tool in helping producers modernize in order to take advantage of comparative advantages. Measured in constant 1994 pesos, total resources allocated to *Alianza* increased from 2 to 3.2 billion pesos between 1996 (year of the program's inception) and 2000. During that same period, the total number of producers that benefited from *Alianza's* programs also expanded from 1.88 million to 4.54 million production units. Consequently, the average amount of resources (in 1994 pesos) allocated to these units dropped from 1,100 to 710 pesos.

Loans for the agricultural sector have also experienced a serious drop. Perhaps the most dramatic indicator here is provided by data on commercial loans to the agricultural sector. During the period 1994-2000 total commercial loans for agriculture measured in constant 1994 pesos dropped by more than 76% (from 38,523 to 9,216 million pesos). This figure covers loans for agricultural, as well as livestock production. In the case of commercial credit for agricultural production, the reduction is greater than 71% (from 20,659 to 5,944 million pesos). This of course is consistent with the evolution of commercial credit for the entire economy which dropped by 58% during that same period. One of the most important explanations here is that monetary policy has maintained a restrictive posture in order to harness inflationary pressures.

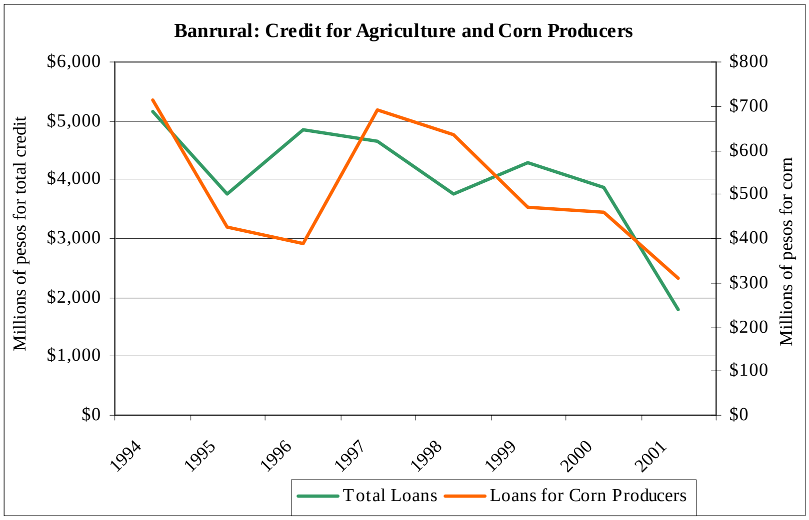
Figure V



Source: Comisión Nacional Bancaria y de Valores (CNBV).

Another indicator of this is provided by the evolution of loans granted by the State-owned Bank for Rural Credit, BANRURAL. Measured in constant terms (1994 pesos), the portfolio of total loans operated by BANRURAL dropped from 5.1 to 1.7 billion pesos between 1994 and 2000. Also measured in 1994 pesos, loans for corn producers dropped from 713 to 311 million pesos during that period.

Figure VI

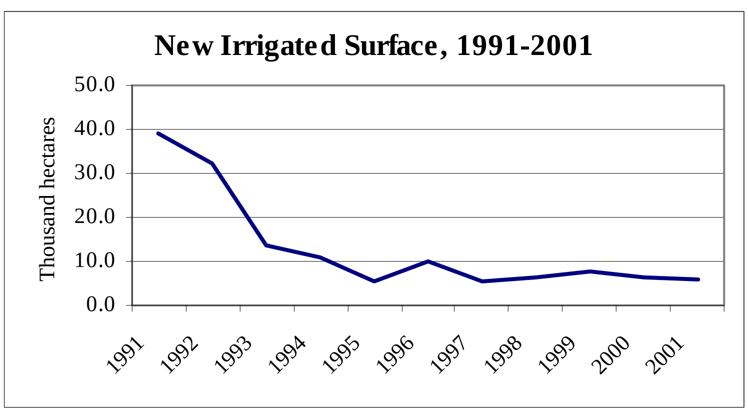


Source: Comisión Nacional Bancaria y de Valores.

Although insurance against crop failure has never covered a very significant share of total cultivated surface, since the NAFTA entered into force, it has experienced a dramatic fall. Insurance against crop failure dropped from 455 in 1994 to 197 thousand hectares in 2001. This is an important indicator in view of the fact that the difference between cultivated and harvested land has increased and this may reflect a higher coefficient of crop failure (see Figure II above).

Finally, expenditures in agricultural infrastructure have also stagnated. At the beginning of the decade, new irrigated land reached thirty nine thousand hectares per year. By 2001 this surface had dropped to a mere six thousand hectares.

Figure VII



Source: Primer Informe de Gobierno, 2001.

To summarize, investment in the agricultural sector experienced significant reductions during the past decade. This is unfortunate because during this period the agricultural sector was exposed to the pressures of trade liberalization. New investments were required in order to meet the challenge of reduced prices, increased competition from imports and greater competition in the international markets for Mexico's agricultural exports. Productivity-enhancing investments needed to reap the benefits of Mexico's comparative advantages, as well as investments to increase production intensity, have not been flowing to the agricultural sector. This helps explain why the sector's GDP has stagnated and why the trade balance has not been improving. The lack of investment in agriculture may also be responsible for the expansion of cultivated surface and ensuing environmental effects.

III. EVOLUTION OF MEXICO'S CORN GROWING SECTOR

The two studies (Levy and van Wijnbergen 1995, 1992) justifying the inclusion of corn in NAFTA forecasted important reductions in total corn output as domestic corn prices aligned with international prices. These forecasts are based on production functions that are more akin to a partial equilibrium scheme in which corn prices are the only determinant of total corn output. These forecasts did not prove to be correct, as output and cultivated surface increased during the decade. However, the evolution of the corn sector was not uniform and this section examines the salient features of this process, as well as its causes.

Table I presents annual data on corn output and cultivated surface in Mexico for the period 1990-2000. Output climbed rapidly starting in 1992-1993, and reached the historical high level of eighteen million tons in 1994-1995. In 1997 output dropped, but the eighteen million ton figure was recovered in 1998. Since then, output dropped and reached the seventeen million ton level in 2000. In spite of this reduction, the level of output was still 17% greater than it was at the beginning of the decade. Although the increment may not appear spectacular, it is surprising because it coexists with a price decrease of more than 40% in corn prices.

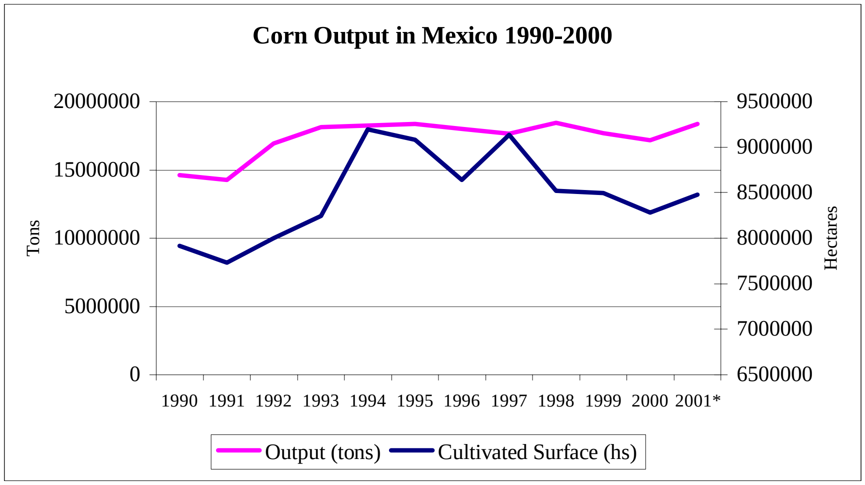
Cultivated surface increased from 7.9 million hectares in 1990 to nine million hectares in the middle of the decade. After 1997 this level dropped to 8.2 million hectares in 2000. The amount of cultivated surface dedicated to corn increased during the decade at a slower rate than output, but yield at the national level increased modestly **.**15 tons during the decade. We return below to a more detailed analysis of yields.

Table II

Corn Output in Mexico 1990-2000

	Cultivated Surface (hs)	Output (tons)	Yields by hectare
1990	7917518	14635439	1.85
1991	7730038	14251500	1.84
1992	8002675	16929342	2.12
1993	8247607	18125263	2.20
1994	9196478	18235826	1.98
1995	9079636	18352856	2.02
1996	8638735	18023626	2.09
1997	9133074	17656258	1.93
1998	8520639	18454710	2.17
1999	8495875	17706375	2.08
2000	8283167	17191072	2.08
2001*	8475917	18356526	2.17
(*) Forecasted by SAGARPA.			
Source: SAGARPA.			

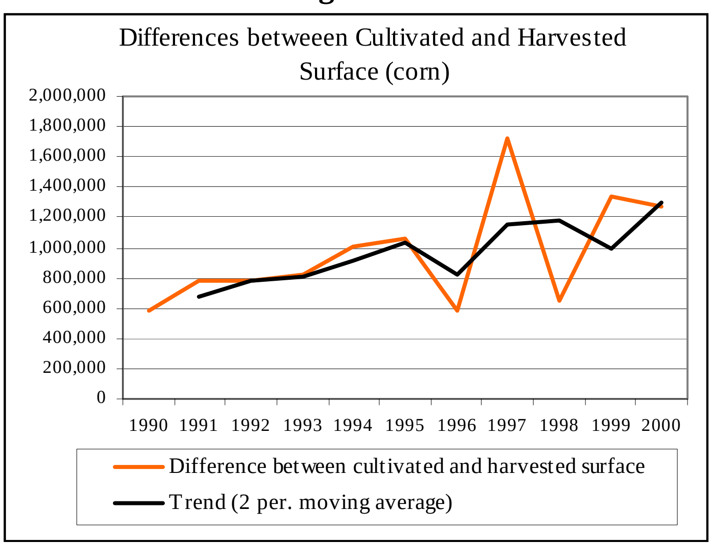
Figure VIII



Source: SAGARPA.

It is important to note that, as with aggregate data for all crops, the difference between cultivated surface and harvested surface allocated to corn increased during the decade. In 1990, the coefficient was 1.07; by the end of the decade it had increased slightly to 1.18. As noted before, this can be interpreted as the coefficient of crop failure. It indicates that for each harvested hectare in 2000, almost 1.2 hectares had to be cultivated or planted.

Figure IX



Source: SAGARPA.

A more disaggregated analysis at the state level shows that there are important regional differences behind the evolution of this coefficient. The following table presents data on the difference between cultivated and harvested surface in the nine states registering the most important expansion of cultivated surface. While the states of Oaxaca and Veracruz record a significant decrease in this coefficient, the other seven states show an increment in this difference during the decade. Particularly important in this context are the states of Chiapas, Tabasco and Guerrero, where rural poverty is pervasive and a great number of corn producers operate. The case of Oaxaca is also important because it also has high indexes of poverty and social marginalization. Although this state shows a decrease in the difference between cultivated and harvested surface, the data for the entire series reveal three peaks of exceptionally high levels (exceeding 100,000 hectares) in the difference between cultivated and harvested surface. This suggests cultivated surface is more vulnerable to changes in climate and precipitation than in other states. In turn, this level of vulnerability is an additional cause for the expansion of cultivated surface in the light of high tortilla prices.

Table III

Differences between Cultivated and Harvested Surface in Corn Production by State

	1990	**2000**
CHIAPAS	7,001	24,302
VERACRUZ	63,060	22,330
OAXACA	94,704	43,919
GUERRERO	2,544	19,682
YUCATÁN	1,526	11,750
CAMPECHE	6,338	7,065
TABASCO	2,322	17,285
QUERETARO	7,741	47,659
QUINTANA ROO	7,813	25,382

Source: SAGARPA.

If we divide corn-producing states into two groups, with the top ten producers on one side, and the other twenty-two states in the other, we can observe that average yields increased in both groups. Yields in the ten most important states are higher, but they are in the same order of magnitude as yields in the rest of the corn producing states.

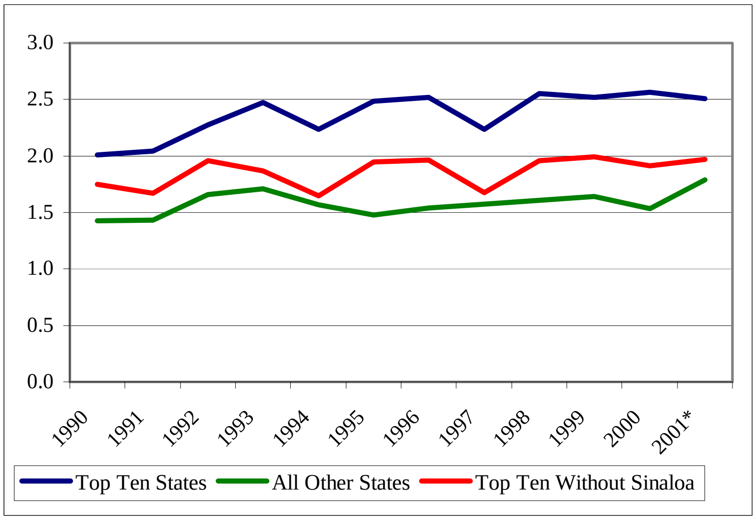
Yields increased by 25% in the top ten states, as well as in the remaining twenty-two states. However, if we exclude Sinaloa, yields in the top nine states only increased by 12%. The reason for this is the spectacular growth in yields in Sinaloa that jumped from 2.6 to 6.5 tons per hectare between 1990 and 2000. This means that, in fact, yield increments were only marginal for these nine states and only when data for Sinaloa is included yield evolution for the top ten states appears more favorable.

Table IV

Average Yields by Groups of Corn Producing States

Year	Top Ten States	All Other States	Top Ten Without Sinaloa
1990	2.0	1.43	1.75
1991	2.0	1.43	1.67
1992	2.3	1.66	1.96
1993	2.5	1.71	1.87
1994	2.2	1.57	1.65
1995	2.5	1.48	1.95
1996	2.5	1.54	1.96
1997	2.2	1.57	1.67
1998	2.6	1.61	1.96
1999	2.5	1.64	1.99
2000	2.6	1.53	1.91
2001*	2.5	1.79	1.97

Figure X
Average Yields by Groups of States 1990-2000



Source: SAGARPA.

The commitments under NAFTA promised a significant restructuring of the structure of output in Mexico's agriculture and, especially, in the corn producing sector. However, in the corn sector the set of the top ten states that contribute with 76% of total corn output has remained surprisingly stable. The only important change is that at the beginning of the decade corn output in Sinaloa barely surpassed 300,000 tons and this state was therefore not within the top ten corn producers. By 1993 it had trebled its corn production. In 1993 Sinaloa was producing 2.4 million tons of corn, and attained the number one position in corn production, a position it has not relinquished to date.

Table V

Evolution of Top Ten Corn Producing States, 1992-2000						
	1992		**1993**		**2000**	**Yields 2000**
Jalisco	2421193	Sinaloa	2449096	Sinaloa	2319475	6.5
EdoMex	1901215	Jalisco	2379659	Jalisco	2158926	3.1
Chiapas	1607369	Chiapas	1594100	Chiapas	1887370	1.9
Puebla	1164429	Guanajuato	1255706	EdoMex	1757710	2.9
Guerrero	983801	EdoMex	1233450	Veracruz	1242284	1.8
Sinaloa	960109	Michoacán	1060769	Guerrero	1181463	2.3
Michoacán	920566	Puebla	1018884	Michoacán	1103374	2.2
Veracruz	895397	Guerrero	886836	Puebla	869858	1.6
Guanajuato	784174	Veracruz	779912	Oaxaca	817497	1.3
Oaxaca	512818	Oaxaca	547654	Guanajuato	648262	1.6

Source: SAGARPA.

In 1990 Sinaloa allocated 121,458 hectares to corn production, but this expanded four fold by 1994 to 472,202 hectares. Although a reduction was registered by 2000 to 378,346, Sinaloa retained its number one position in corn production due to its very important gains in yields. This means that although cultivated surface was reduced between 1994 and 2000, producers in Sinaloa have maintained the preeminence in corn production because of the important gains in yields. For these capital-intensive producers corn production retains its relative profitability vis-à-vis other crops. Although corn prices have dropped, as was pointed out above, the prices of other crops have also experienced significant reductions. Cost structures of Sinaloa's producers allow them to retain their competitiveness in spite of these downward trends in agricultural prices.

It is important to examine the evolution of cultivated surface devoted to corn and other crops, because much of NAFTA's restructuring implied, at least in terms of objectives, allocating more land to the production of more profitable and export oriented crops. As can be observed from data in Table IV, Sinaloa experienced the largest increment in cultivated surface devoted to corn during the decade, but this coincided with a 12% reduction in land allocated to all other crops. This means that although Sinaloa continued to be the country's most important producer in horticulture, corn absorbed some of the land that could be devoted to other crops which were considered, at the time of the NAFTA negotiations, linked to Mexico's comparative advantages.

In the case of Chiapas, Oaxaca, Veracruz and Guerrero, cultivated surface for corn, as well as for all other crops, expanded significantly. These states concentrate 38% of all corn producing units in Mexico, and the majority of these units are small holdings operating with less mechanization, using more traditional land races and relatively low levels of chemical inputs. Yields in these four states expanded during the decade, but at a very moderate rate (on average yields increased by .45 tons per hectare). As can be seen below, rural poverty in these states is pervasive. All of this suggests that the expansion of cultivated surface in corn, in spite of price reductions, is a response of poor households to the combined environment of low corn prices and higher tortilla prices.

Table VI
Percentage variation of Cultivated Surface of corn and all other crops

	% of Corn from 1990 to 1994	% of the rest of crops from 1990 to 1994	% of corn from 1994 to 2000	% of the rest of crops from 1994 to 2000	% of corn from 1990 to 2000	% of the rest of crops from 1990 to 2000
Sinaloa	288.78%	-24.83%	-24.53%	17.07%	193.40%	-12.00%
Chiapas	3.18%	21.53%	33.50%	19.20%	37.74%	44.87%
Oaxaca	30.25%	11.72%	-5.84%	11.69%	22.64%	24.77%
Veracruz	6.07%	3.05%	4.66%	21.15%	11.01%	24.85%
Guerrero	-1.18%	0.18%	9.81%	33.39%	8.51%	33.63%
Michoacan[1]	8.65%	-13.90%	-8.35%	40.86%	5.53%	21.29%
Puebla[1]	-5.99%	-3.20%	-8.83%	36.10%	1.58%	31.75%
Jalisco[1]	3.84%	-6.73%	-6.59%	34.20%	1.29%	25.17%
Guanajuato	16.76%	-13.48%	-18.87%	7.27%	-5.28%	-7.19%
Estado de México	-6.33%	-15.60%	-6.82%	101.57%	-12.72%	70.12%

Source: Table constructed for this paper with data from SIAP (2001), SAGARPA, Mexico.
[1] Percentage variation on the Cultivated Surface from 1990 to 1999, numbers with italics

This brief summary shows that corn production in Mexico has not experienced the dramatic changes that many expected from the inclusion of this crop in the NAFTA. In spite of a 44% drop in corn prices, total corn output remained at the historical high levels it attained in 1993-94. This paradox requires a more detailed analysis of the evolution of relative prices in the agricultural sector. Together with the data on public expenditures and the lack of commercial credit in agriculture, these are the main explanatory variables behind the evolution of corn production in Mexico. In the following section we analyze the evolution and volatility of agricultural prices.

Corn Prices

As pointed out before, the evolution of output must be seen in the light of a very unfavorable change in corn prices. Domestic corn prices had started to fall since 1990 as a direct consequence of a fall in subsidies for guarantee prices. By 1993, corn prices had dropped by 20% in real terms. This trend continued and was accentuated after trade liberalization took place. Between 1994 and 2000, domestic corn prices dropped by 44% in real terms.

Natural logarithms of constant prices for selected crops during the decade 1990-2000 are presented in Figure III showing a general declining tendency for all selected crops. This reveals that although the price of corn was falling in real terms during this period, the prices of the other crops were also falling, and at a faster rate.[5]

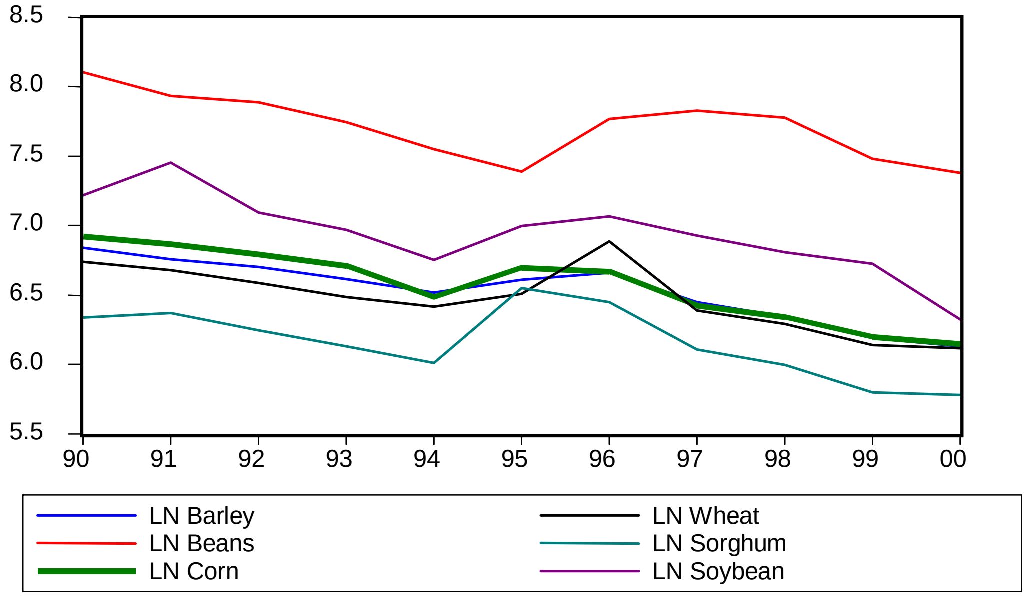
Table VII
Constant prices for selected crops.
Pesos per ton, Base 1994

	Barley	Beans	Corn	Sorghum	Soybean	Wheat
1990	$934.81	$3,306.09	$1,013.76	$567.28	$1,356.85	$843.66
1991	$860.41	$2,782.26	$959.13	$583.06	$1,718.86	$794.91
1992	$815.56	$2,660.10	$893.66	$515.85	$1,200.00	$722.07
1993	$745.53	$2,307.38	$821.21	$458.10	$1,064.14	$657.76
1994	$678.89	$1,900.74	$656.22	$406.87	$857.45	$610.79
1995	$742.67	$1,619.48	$808.58	$697.44	$1,091.57	$668.57
1996	$782.66	$2,350.69	$790.87	$629.00	$1,172.42	$978.42
1997	$629.86	$2,500.05	$618.66	$448.68	$1,018.49	$596.90
1998	$568.84	$2,381.23	$570.08	$401.42	$901.20	$541.03
1999	$486.86	$1,775.65	$491.78	$331.04	$833.26	$462.74
2000	$457.70	$1,603.21	$467.65	$324.38	$556.30	$453.20

Source: Poder Ejecutivo Federal, Primer Informe de Gobierno, 2001, p. XX, Mexico.

[5] Prices are a critical signal for agricultural producers, but other variables are also important because cost structures are key determinants for profit rates. Unfortunately, we do not have detailed data on costs of inputs so relative profitability cannot be incorporated into our analysis.

Figure XI
Natural Logarithms of Basic Grains' Real Prices, 1990-2000
(Base 1994)

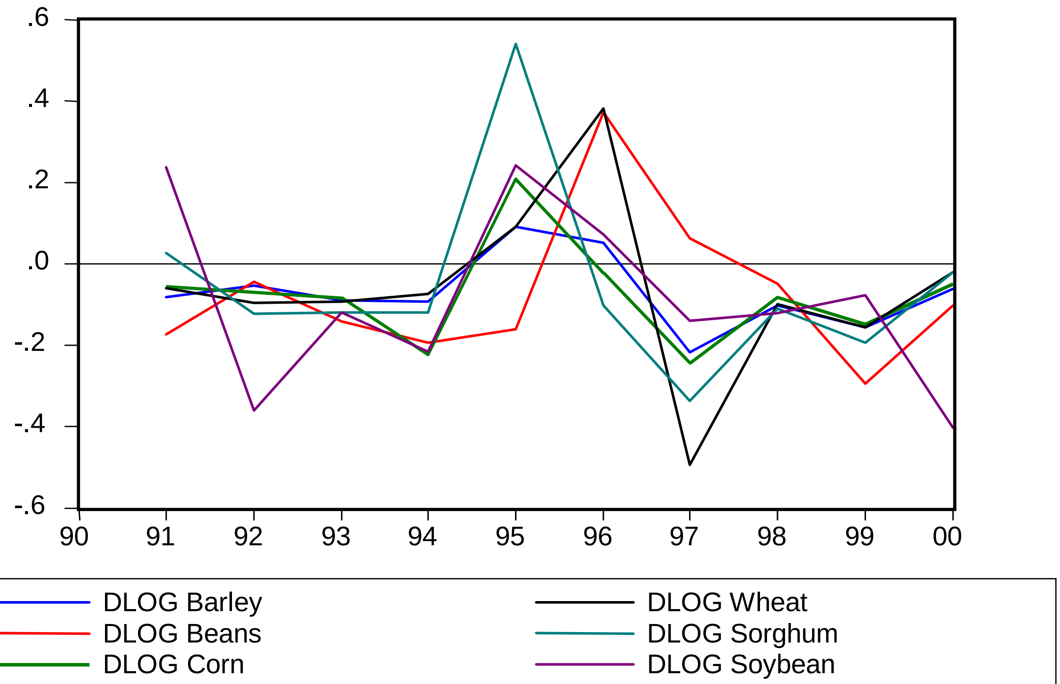


Source: Author's calculations with data from SAGARPA.

In addition, the volatility of other crops' prices was greater. Figure IV presents the evolution of the first differences of the natural logarithm of the constant prices for these crops. The first differences of the natural logarithms show the real changes in growth rates for every crop. We can appreciate a great variability in the growth rates of all prices. For example, this figure shows that in 1990, soybean prices were indeed higher than corn, but that difference was absorbed and reverted in 1991. The differences between both crops follow a similar pattern after that year. A similar situation appears when comparing corn and sorghum between 1994 and 1996, and corn and wheat prices between 1995 to 1997.

The first differences of the natural logarithms of the constant prices of the main crops cultivated in Mexico were also regressed against the first differences of the natural logarithm of the constant price of corn. This simple lineal regression shows a clear positive relation between every crop price and the price of corn. This supports the hypothesis that all agricultural prices were highly unstable and responded in the same way to trade liberalization.

Figure XII
Main Crops: First Differences of Logarithms of Constant Prices



Source: Author's calculations with data from SAGARPA.

This pattern helps explain why corn production increased and then remained stable during the decade. Given price volatility, for corn producers the risk of diversifying or changing crops may have actually increased. While corn prices were subjected to a similar process, most producers continued to plant this crop because the technology is well known and therefore the risk of crop failure may appear manageable. In addition, corn remains the key staple crop and provides security for the household in the context of price volatility. Finally, even for states which produce for the market, like Sinaloa, price volatility of other crops also helps explain why cultivated surface for corn increased during the decade.

To conclude, this downward trend has to be analyzed in the context of inflation. Inflation was harnessed during the early part of the decade, although this did not prevent a 36% inflation between 1990-1993 (calculated with 1993 as the base year). This was done through two central policy instruments, the (overvalued) exchange rate, and the control of real wages through social bargaining pacts. In 1993 inflation attained its lowest level. As the 1994 crisis unfolded, the inflation rate accelerated and between that year and 2000, the general consumer price index increased by 246% (calculated with 1993 as the base year). This cumulative inflation is calculated mostly for urban areas. But the downward trend in real prices of agricultural products, together with cumulative inflation, is linked to a negative income effect that has not been compensated through policy instruments such as PROCAMPO and Alianza para el Campo.

III. POVERTY AND MIGRATION

This section examines some of the social implications arising from the NAFTA corn regime. Special emphasis is applied on the relationship between poverty, marginalization and corn production.

In 1998 47% of Mexico's total population (99 million) lived below the poverty line, while 20% lived in conditions of extreme poverty (CEPAL 2000). These figures are based on a concept of poverty relying on a person's capacity to purchase a basket of basic foodstuffs. It does not take into consideration other basic needs in terms of clothing, health services, education and dwellings. According to other estimates, the percentage of Mexico's population living under the poverty line increases dramatically to 71%.[6]

Between 1992 and 1998, average real monetary income declined at an annual rate of 3.2%. Thus, although the Gini coefficient for Mexico's income distribution in 1998 (0.50) showed a marginal improvement with respect to 1992 (0.51), this change is accompanied by a process of intensification of poverty in rural areas.

Table II shows that real monetary income dropped between 1992 and 1998 for all deciles in localities of all sizes.[7] In percentage terms, the drop was more intense for households in localities with more than 2,500 inhabitants (64%) than in localities with less than 2,500 inhabitants (59%). However, already at the beginning of the period the average level of monetary income for households in rural areas was lower than in urban areas. This means that the income reductions may have had a greater impact on the livelihood of rural households.[8]

That poverty intensified in rural areas is underlined by the fact that the number of rural households with incomes below the rural average increased from 62% to 72% during the time period considered, while the equivalent for urban areas remained constant at 75%.[9] Households in the first and second deciles represented 48% of total rural households in 1998, while the equivalent share in urban areas was 11%.

---

[6] Personal communication, Dr. Julio Boltvinik.

[7] Localities are classified by size in two categories (more or less than 2,500 inhabitants). This part of our analysis considers monetary income instead of total (monetary and non-monetary) income. Procedures to make value imputations for several non-monetary income headings, such as "rent" imputed for households which own their dwellings, are marked by serious limitations. Normally, an overestimation of total income occurs when these non-monetary components are included for households in rural areas. As a proxy for rural areas we use the information for localities with less than 2,500 inhabitants.

[8] Rural income distribution was less skewed in 1992 because poverty was more equally distributed in rural areas. By 1998, inequality had increased (together with poverty) in rural areas.

[9] In Table V households were first divided into income deciles. Then each decile was further divided into households in towns of more or less than 2,500 inhabitants. Thus the number of all households in each decile is 10% of the national total, but within each decile the number of households by size of towns varies.

Table VIII

Monetary Household Income by Town Size

(Quarterly data in constant 1994 pesos)

	1992		**1998**	
Current Monetary Income Total Deciles	Townships with more than 2,500 inhabitants	Townships with less than 2,500 inhabitants	Townships with more than 2,500 inhabitants	Townships with less than 2,500 inhabitants
Total (Average)	7,077.00	2,551.00	5,802.00	2,180.00
I	596.00	600.00	457.00	452.00
II	1,377.00	1,335.00	1,107.00	1,069.00
III	2,013.00	1,987.00	1,598.00	1,584.00
IV	2,619.00	2,614.00	2,131.00	2,110.00
V	3,267.00	3,199.00	2,690.00	2,658.00
VI	4,049.00	3,991.00	3,374.00	3,330.00
VII	5,161.00	5,031.00	4,311.00	4,228.00
VIII	6,715.00	6,561.00	5,685.00	5,701.00
IX	9,617.00	9,447.00	8,061.00	8,027.00
X	24,444.00	22,348.00	19,827.00	17,660.00

Source: Salas (2000) with data from INEGI, Encuesta nacional de ingresos de los hogares, 1992 and 1998.

According to official data provided by the National Population Council (CONAPO) the ten most important states from the point of view of migratory flows are the following: Jalisco, Colima, Michoacán, Durango, Zacatecas, Guanajuato, Chihuahua, Oaxaca, Puebla and Veracruz. Six of these states are among the top ten corn producers in Mexico: Jalisco, Veracruz, Oaxaca, Michoacán, Guanajuato and Puebla.

An important item to be considered in this context is the impact of the recession in the U.S. economy on remittances by migrant workers to Mexico. Although it is too early to attempt a precise estimate of the reduction in remittances, a recent study by the Inter American Development Bank (IDB) revealed that 56% of Hispanic immigrants that routinely send remittances to their country of origin have reduced the amount they send home. This study was carried out before the attacks of September 11. The immediate causes behind this negative trend is the loss of jobs (7% of those interviewed had lost their job) and reduced working hours (26% of those interviewed had suffered significant working hours reductions). This situation is aggravated in the case of farm workers because many did not return to Mexico from fear of having trouble crossing back to the United States after the holiday season. This means that there is a seasonal over supply of farm labor.[10] In addition, there is a high cost for individual workers and households paid to send funds into Mexico.

[10] In California it is assumed by state authorities that farm workers live in the U.S. only during the harvest season. However, it is now clear that more and more migrant workers stay for longer periods of time. The uncertainty regarding their ability to return has reinforced this trend. Help in the form of housing is denied to these workers during the Winter months under this assumption, unless they qualify as homeless people.

Poverty is closely associated with levels of social marginalization, but there are important differences between both concepts. Poverty can be defined in terms of low monetary income and reduced asset property. Marginalization covers a wider spectrum of socio-economic conditions: open and disguised unemployment, job precariousness and low remuneration rates, lack of credit to work land productively, lack of access to basic goods and services, structural conditions of dwellings, and schooling levels (Rodgers 1995). In a wider sense, marginalization frequently comprises vulnerability of social groups or individuals to natural disasters.

Thus, the concept of marginalization goes beyond simpler economic indicators such as monetary income or per capita GDP, and involves variables describing with greater accuracy the socio-economic condition of individuals or groups. Marginalization is a concept that encompasses poverty as well as exclusion from economic and social opportunities, and even adequate political representation (Gore et al 1995). Poverty can be overcome when economic conditions improve, while reducing marginalization requires a richer and more complex normative approach providing access to basic services and goods, and eliminating the barriers to economic opportunity.

Marginalization levels provide the frame of reference of survival strategies of individuals, families or entire communities, and they may foster the adoption of short term survival strategies which may ignore long term environmental concerns (Larson and Bromley 1990; Perrings 1989). Thus, the concept of marginalization is of greater usefulness for the analysis of potential sources of pressure on NPA's than simple poverty indicators.

Table IX
Index Ranges and Marginalization Rankings

State	**Municipios**	**Marginalization Levels**
2.36 – 1.13	3.15 – 0.91	Very High
1.00 – 0.39	0.91 – 0.35	High
0.13 - (0.23)	0.35 - (0.76)	Medium
(0.55) - (0.85)	(0.76) - (1.32)	Low
(1.05) - (1.74)	(1.32) - (2.44)	Very Low

Note. Numbers in parentheses denote negative coefficients.
Source: CONAPO (1998).

Although marginalization is a multifaceted concept, some of its dimensions and intensities can be captured through the proportion of a given population without access to basic goods and services. Using techniques of multivariate analysis the National Population Council (CONAPO 1998) prepared a composite index measuring marginalization by state, *municipios* and towns for 1995. This index measures relative deficits over a set of social and economic conditions required to attain minimum well-being levels.[11] The index strata and their range values, as well

[11] The index components at the state level are the following: education (illiteracy and incomplete primary education), dwellings (dwellings without water piping, sewage, or electricity, with dirt floors, and congested household space), population dispersal (proportion of population living in towns with less than 5,000 inhabitants), and monetary income (proportion of employed population earning up to two minimum wages). At the *municipio* level, population dispersal is not included and access to

as marginalization levels for states and *municipios* are shown in the Table III.

Marginalization coefficients in the top ten corn-producing states appear in Table X. More than 30% of total corn output in Mexico originates in four states with very high marginalization indexes (Chiapas, Guerrero, Oaxaca and Veracruz). An additional 11% comes from the states of Puebla and Michoacán which show high marginalization coefficients. Thus, 41% of total corn production originates in states which have very high or high marginalization indexes.

Table X
Social Marginalization in the Top Ten Corn-Producing States

State	Marginalization Index	Share of Total Corn Production	Number of Production units	Share of All Production Units
Chiapas	2.36	11%	253,644	10%
Guerrero	1.91	7%	169,122	7%
Oaxaca	1.85	5%	281,326	11%
Veracruz	1.13	7%	248,598	10%
Puebla	0.8	5%	265,866	11%
Michoacán	0.39	6%	130,319	5%
Guanajuato	0.13	4%	110,073	4%
Sinaloa	-0.21	13%	40,100	2%
Jalisco	-0.6	12%	108,204	4%
Edomex	-0.74	10%	246,806	10%

Source: SAGARPA and National Population Council.

These six states have 54% of the total number of corn producing units (according to the 1990 Agricultural Census).[12] As can be seen from Table VI, these six states saw a significant expansion of the cultivated surface for corn during the period 1990-2000. This lends support to the view that, for poor households, expansion of corn production is an immediate response to the challenges of falling prices and an adverse economic environment.

The regional distortions marking Mexico's socio-economic landscape are replicated in terms of social marginalization in Map II. Marginalization is pervasive in the southeastern states. Four states (Chiapas, Oaxaca, Guerrero, Veracruz) exhibit very high marginalization indexes, while three other (Yucatán, Campeche and Tabasco) have high marginalization indexes. This segment of the country's territory is connected with four other important states in central Mexico with high marginalization indexes (Puebla, Hidalgo, San Luis Potosi and Zacatecas).

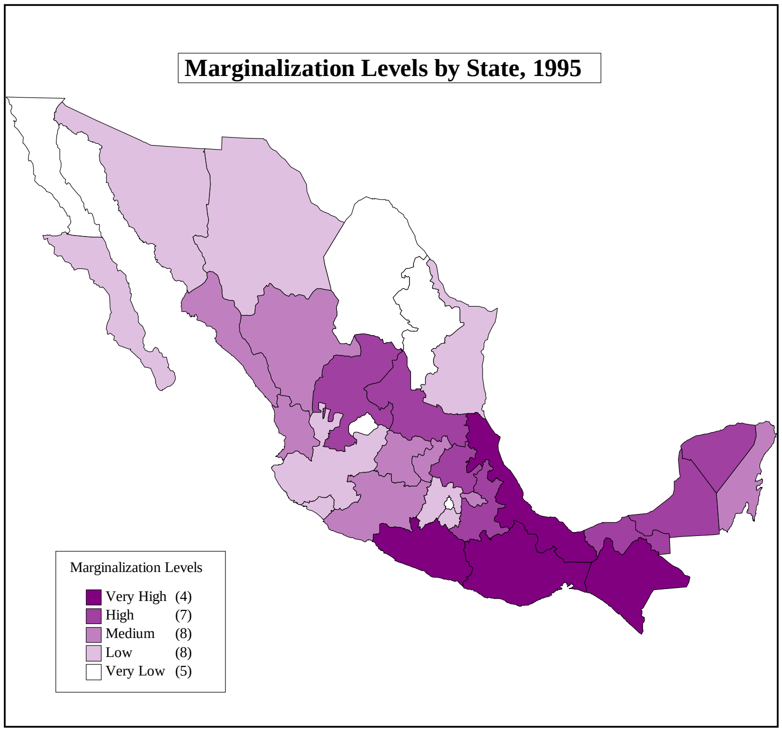
The four states where localities with Very High marginalization indices predominate are states with a great number of corn producing units: Chiapas, Guerrero, Oaxaca, Veracruz. These

education is captured only through illiteracy rates. Briefly, the index uses a set of weights that are the first principal component that results from a factor analysis on eight variables.

[12] The number of corn producing units used here is the latest figure available. The agricultural census for the year 2000 was not carried out. Because the migratory flows that were supposed to take place under the NAFTA have not yet materialized, these numbers can be confidently considered to be a good approximation of present day conditions.

states concentrated 952,690 corn producing units (according the 1990 Census) or 38% of all corn producing units in Mexico, while corn output from these four states represents 30% of the country's total output. In the next level we find states with a High incidence of marginalization: Yucatan, Campeche, Tabasco, Puebla, Hidalgo, San Luis Potosi and Zacatecas. The number of corn producers in these states (again according to the 1990 Census) represents 30% of the country's total number of corn producers. However, in terms of output, these states account for only 14% of total corn output.

Map I



Source: Prepared by author with data from CONAPO (1998).

In this context, it is important to review the evolution of corn output by states. Corn output expanded by 4.7 million tons in fourteen states during the period 1990-2000, and contracted by 2.1 million tons in eighteen states. Of the eleven states mentioned in the previous two paragraphs, three experienced a reduction in output: Puebla, San Luis Potosí and Zacatecas. Only Puebla is among the top ten producers, but Zacatecas and San Luis Potosí occupy positions eleven and thirteen respectively in the ranking of corn production.

The expansion of corn output in Chiapas, Guerrero, Oaxaca and Veracruz during the period in question surpassed 1.92 million tons, equivalent to 40% of the total output expansion of corn. The fact that these states have very high marginalization indexes account for such an important share of total output expansion may suggest that survival strategies of poor households involve growing more corn. This has taken place mainly through the expansion of cultivated surface (as shown in Table IV) and to a lesser degree through a modest growth in yields (an average of .4 tons per hectare during the decade).

More research is required to determine the environmental and social impacts of this expansion of corn production by states. The potential effects on land resources are of course of primary interest given the high erosion and loss of topsoil rates in these states where most highland cultivation takes place in areas with steep slopes and high precipitation rates. In addition, the use of fertilizers and other chemical inputs requires more attention. But perhaps the most important environmental dimension continues to be the effects on the management of genetic resources, to which we now turn our attention.

IV. ENVIRONMENTAL IMPLICATIONS: GENETIC RESOURCES

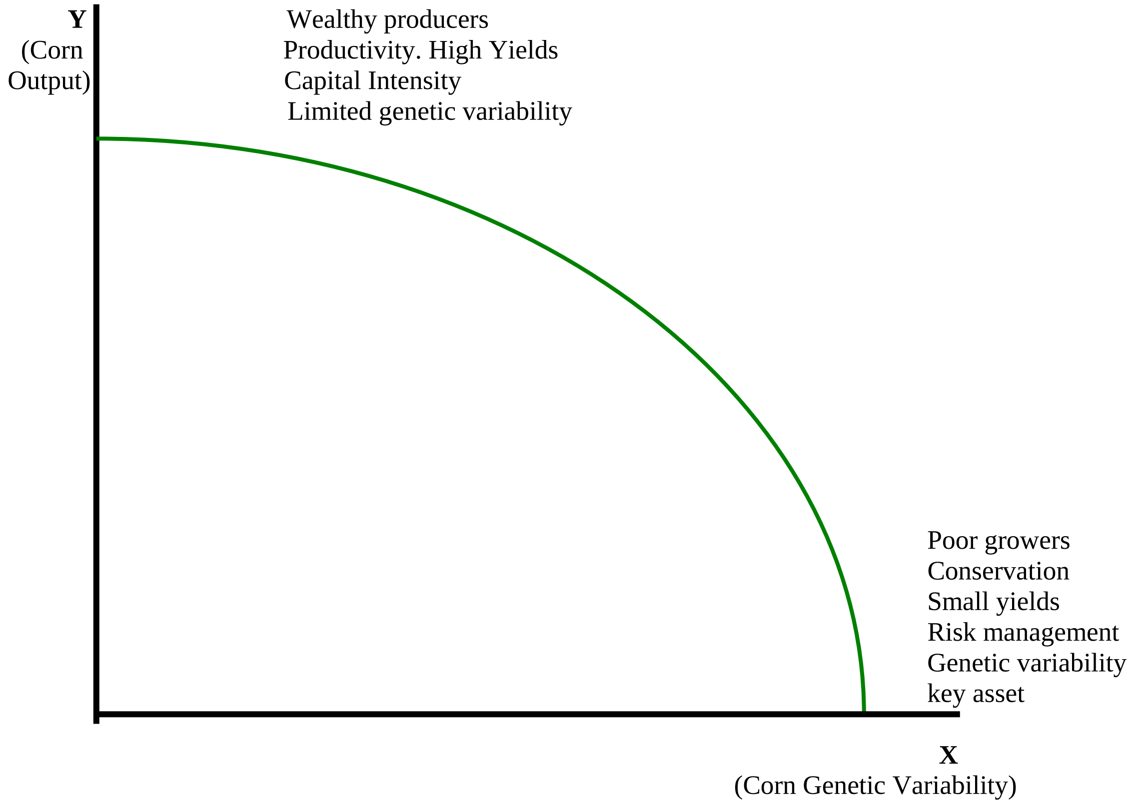
Perhaps the most important trait of corn production in Mexico is its high degree of heterogeneity. Production conditions are extremely varied and they form a complex matrix of social, economic, technological and natural variables. Because corn undergoes very intense genetic x environment interactions, it shows a greater capacity than the other major cereals (wheat, rice, barley, sorghum, millet, oats) to adapt to a vast range of ecological conditions. It grows at altitudes of up to 3000 masl, but can also be found at sea level, and its mean growing season temperatures can exceed 26º C or may be as low as 12.5º C. The capacity of corn germplasm to adapt to such a wide variety of ecosystems has turned it into an important component in the productive strategies of corn growers, especially in the case of the poorest farmers.

For many of Mexico’s corn growers, the genetic variability of corn is one of the most important technological assets (Nadal 2000, 1999). In addition, a key feature of this system of production is that it is an open genetic system in which migration between fields is the common rule (Serratos-Hernández, Islas and Berthaud 2001; Louette 1995; Louette and Smale 1996).

Mexican corn varieties are well adapted to changes in rainfall (especially to the interruption of rains at the beginning of the plant’s growing cycle), humidity, climate variations, pests, winds, low nitrogen or acid soils. Poor growers normally have to rely on soils of inferior quality, where yields are low and risks of crop failure are high. Thus, the local landraces that have undergone a long and systematic process of adaptation to the diverse agro-ecosystems in Mexico are a critical element in their resource endowment. But in order to use these varieties, producers must possess refined information on the array of relations between seed characteristics and soil quality, weather and climate conditions, humidity levels and drainage patterns, topographic features, and pests. This information also covers complex intercropping systems involving several leguminosae (kidney beans and broad beans), cucurbitaceae (different types of squash), and a wide variety of herbs.

This is why growers that use corn’s genetic variability as a key technological asset are the curators of this resource (Nadal 2000, 1999). They have maintained and developed this resource through a continuous process of dynamic exchanges of open pollinated varieties, local cultivars and frequently through the adaptation (or “creolization”) of improved varieties and hybrids generated in the formal agricultural research centers. The knowledge they possess on their agro-ecosystems enables them to maintain and continuously enrich this stock of genetic resources.

Figure XIII
Genetic Variability and Productivity Trade-off in Corn Production



Source: Adapted from Smale, Aguirre, Bellon et al (1999).

Figure XIII presents in simplified terms the relation between the presence of rich genetic corn variability and low yields, and low variability and high yields. The case of poor corn growers who are endowed with low quality land but high rich corn variability is described by the southeast segment of the curve. The case of rich growers, with high quality land but poor corn variability lies in the northeast portion of the curve. The curve itself does not imply the existence of a functional relationship, but it does show the wide differences existing between these two classes of producers.

In the rationale of NAFTA's corn regime these poor producers appeared to be non-competitive because their yields are very low, especially if compared with yields in the U.S. corn belt. In addition, subsidies are required to keep these producers operating, so a significant fiscal cost, with its repercussions on the overall fiscal deficit, had also to be taken into account. Thus, these poor producers were considered to be redundant and market forces, through trade liberalization, had to operate a reallocation of resources.

This line of reasoning is inaccurate. The correct assessment of these producers' competitiveness must take into consideration their ability to provide the environmental service involved in the conservation and development of these genetic resources.

Evaluating and comparing international efficiency and competitiveness levels is a complex task. In the case of corn growers, this comparison cannot be limited to yield levels. This is a purely physical parameter that is prone to manifold misinterpretations because it ignores several critical variables. For one thing, it leaves out the crucial fact that yield variations originate in different agrological and ecological conditions.[13]

Thus, a farmer growing corn in the U.S. corn belt may attain yields in the order of 12 or 14 tons/hectare. But this result, which appears to compete favorably with yields of Mexican producers which barely surpass 2t/ha, is not conclusive. The typical farmer from Nebraska will not be able to compete with the Mexican farmer if he sows his corn seed under the same harsh conditions of abiotic and biotic stresses dominating much of Mexico's agricultural landscape.

There are various estimates of the amount of cultivated land dedicated to corn production planted with high-yield varieties in Mexico. A recent estimate (Serratos-Hernández, Islas and Berthaud 2001) sets this at 25%. This estimate is consistent with other assessments considered in Nadal (1999), and with the data from the 1991 Agricultural Census. This low rate is due to the well known fact that landraces perform better than hybrids under stress and in poor or shallow soils (see Nadal 1999 and references therein).

It is unlikely that these structural conditions changed in the past three years.[14] Our conclusion is that genetic erosion caused by displacement of landraces due to the massive introduction of hybrids has not been taking place in Mexico. The resilience of local landraces even in view of official policies like the "Kilo por kilo" program (which promoted the exchange of local landraces for improved varieties and hybrids in order to attain productivity increases) has been confirmed by other analysts (MacMillan and Aquino 1996; Ortega Paczka, personnal communication).

This viewpoint is confirmed by the description of maize landraces in Mexico presented in Serratos-Hernandez, Islas and Berthaud (2001). Summarizing, these analysts report that landraces that were described and collected since the 1940's. The study concludes that in most of Mexico's macro-regions there exist, in varying degrees of mixture, the landraces of maize described in the classic Wellhausen et al study of 1952 and summarized in the data base of LAMP (Latin American Maize Program of CIMMYT). This stock of germplasm which has so far been conserved and developed *in situ* by Mexico's producers will exchange genetic information with transgenic maize, should this technology be deregulated and used in Mexico.

Transgenic Corn

Genetically modified corn using modern biotechnologies to introduce transgenic material into the plant's genome is a subject of great interest in the context of this study. There are three closely related questions when considering this theme. The *first* is related to the use of

[13] It also ignores the role of subsidies and other economic considerations, such as the availability of credits and insurance against crop failure, etc. Some of these elements may be considered as part of a economic system against which local producers must compete in international trade, but others, like direct and indirect subsidies, cannot be factored into the comparison in this manner. This is why the international trade system incorporates control mechanisms and legal instruments to rid the playing field of these unfair elements.

[14] Ortega Paczka, personnal communication (December 2001).

transgenic corn in Mexico's agricultural sector in response to economic pressure to use new production techniques. This pressure comes from NAFTA-related imports of corn. If growers in the commercial sector use this technology, there may be risks to biodiversity stemming from this event.[15] The *second* question concerns imports of transgenic corn from the United States. Beyond the debate concerning impacts to human health, imports of transgenic corn can pose risks for local landraces, their wild relatives, as well as the integrity of the stock in germplasm banks if sown by growers in Mexico. And the *third* question concerns the risks that sowing of transgenic corn may pose for biodiversity in Mexico's ecosystems.

What will be the rate of adoption of transgenic corn by Mexican growers? The diffusion process of any given technological innovation is a function of the rate of imitation, and this depends on profitability, competition patterns, the structure of the branch or sector, as well as the expansion or contraction rate of the sector's output. Profitability is closely dependent on the appropriateness of the technology to local conditions. Transgenic corn would be no exception to this well known rule: its diffusion rate in Mexico's agriculture will depend of its degree of appropriateness to local conditions.[16] But, another aspect of the diffusion of this technology that must be taken into account is related to the dispersal of transgenic material through cross pollination with other maize varieties and maize's wild relatives. We return to this point below.

In order to analyze how well suited transgenic corn is to Mexican conditions, we need to know more about its potential benefits to growers. The assessment of the risks and potential benefits arising from the presence of transgenic corn in Mexico's rural landscape involves examining if the technology of transgenic corn is appropriate for Mexico. This is a first step because the introduction of transgenic varieties of corn could lead to another episode of genetic erosion if local landraces are displaced. But the diffusion of this technical innovation depends on its adaptability to Mexico's agrological ecosystems, and more specifically, to the different varieties of biotic and abiotic stress that mark Mexico's countryside.

So far transgenic corn has not been designed for use in the agro-ecosystems that prevail in Mexico. Transgenic corn comes basically in two varieties: so-called Bt corn and herbicide resistant corn. The first incorporates the gene of the *Bacillus thuringiensis* and was specifically designed for a pest that is frequent in temperate regions. This pest is the European corn borer (*Ostrinia nubilalis*), an insect from the genus lepidoptera which abounds in the United States' corn belt. But the most important insect pests affecting Mexico's corn growers are the larvae of two insects: Southwestern Corn Borer (*Diatraea grandiosella*), in Mexico known as gusano cogollero, and the Fall Armyworm (*Spodoptera frugiperda*), both from the genus coleoptera. These two pests are normally attacked by direct spraying of pesticides by crews walking through the corn fields because the larvae of these insects are well lodged inside the plant's stalk or penetrate deep inside the whorl. Application of pesticides requires precise targeting and this can only be attained by spraying with crews of workers walking through the rows in the planted fields. This method maximizes the effects of the sprayed chemicals, but poses a serious problem of direct exposure to acutely toxic pesticides. The introduction of corn varieties

[15] Risks to human health must also be evaluated. We shall return to this point in our future research.
[16] Profitability will also have to be ascertained. This will depend on the relation between Mexican cost structures, as well as existing subsidies, and the usual comparison with final market prices.

effectively reducing the need for these pesticides would have significant positive human health effects.

Before 1998 Mexico's government authorized experimental testing for Bt corn in order to test for the expression of the Bt gene. These tests were carried out under strict conditions of isolation and the complete maturity of the plants was interrupted so there was no pollination.[17] However, during the tests, it was found that the *Diatraea* pests, which are predominant in Mexico, showed resistance to the Bt gene. Although it is possible that these pests may be affected by other Bt proteins, this research is still to be carried out.[18]

It has been stated by some analysts that Bt corn may reduce the risk of aflatoxins in corn. However, the vectors of the fungi that bring about the presence of these toxins are from the order coleoptera and not lepidotera. This means that Bt corn is not an effective response to these insects and therefore, the fungi associated with aflatoxins will not be affected by Bt corn.

Altieri on yields from transgenic crops: Altieri (1998): "Recent experimental trials have shown that genetically engineered seeds do not increase the yield of crops. A recent study by the USDA Economic Research Service shows that in 1998 yields were not significantly different in engineered versus non-engineered crops in 12 of 18 crop/region combinations. In the six crop/region combinations were Bt crops or HRCs fared better, they exhibited increased yields between 5-30%. Glyphosphate tolerant cotton showed no significant yield increase in either region where it was surveyed. This was confirmed in another study examining more than 8,000 field trials, where it was found that Roundup Ready soybean seeds produced fewer bushels of soybeans than similar conventionally bred varieties."

If transgenic corn, such as Bt corn or herbicide resistant corn, is not a appropriate technology given Mexico's conditions, then the diffusion of this technology will not threaten local landraces. Genetic erosion through the displacement of local landraces by transgenic corn will probably not happen if the transgenic material is limited to Bt and herbicide resistance.

On the other hand, there are many other transgenes in the pipeline of agro-biotechnology firms and their laboratories (Serratos et al 2001). These include aluminum tolerance, apomixis, vaccines, degradable plastic products, quality protein genes and Mutator regulating elements from various landraces (for example, Zapalote Chico). Whether these transgenes are better suited for conditions in Mexico remains to be seen. Obviously, more research is required to determine this and to assess risks for local corn landraces and biodiversity in general.

The second question concerning transgenic corn is related to the composition of total corn imports under NAFTA's regime, and the final destiny of imported transgenic corn. Mexico's corn imports from the United States probably contain significant amounts of transgenic corn. It

---

[17] This explains why there is no data on yields on these tests.

[18] In the case of experimental testing with herbicide resistant cotton (where more than 40,000 hectares were involved) it was found that intensity of insecticide was reduced. However, the use of insecticide that was reduced is a chemical that targets the pink worm which is not a important pest in Mexico's cotton fields. Thus, the result was normal and the tests showed skewed results. On the other hand, it remains debatable if the official technical standard (NOM 056) that was used to justify the release of transgenic material for tests does in fact offer legal support for this measure.

is impossible to quantify in precise terms the amount of transgenic corn that has been imported. The amount of transgenic corn produced in the United States probably surpasses 30% of total output. But this does not mean that transgenic corn imported from that country is 30% of total imports. It could be more or less. Taking into account the fact that European countries have imposed prohibitions and various restrictions on imports of transgenic corn, it is not altogether unreasonable to suppose that the proportion of transgenic corn in Mexican imports is probably more than 30%.[19] If this is so, then Mexico may have imported more than 2 million tons of transgenic corn in 2001.

Imported corn from the U.S. is basically destined for direct and indirect human consumption, not for seed. However, nothing will prevent growers who buy these seeds in local or regional markets, to use them as seed stock if the need arises. Because transgenic corn will be mixed with non-transgenic corn, it is reasonable to expect that some of the transgenic corn will find its way into Mexican corn fields. If this happens, transgenic corn and local landraces will interact and a two-way gene flow will be established. This will also happen with corn's wild relatives, teosinte and *Tripsacum*.

In 2001, two independent studies confirmed the presence of transgenic material in local landraces in Oaxaca and Puebla. A study by Quist and Chapela (2001) reports the presence of introgressed transgenic DNA constructs in native maize landraces grown in the southern state of Oaxaca. The research sampled whole cobs of native landraces from four fields in two locations in the Sierra de Juárez, north of the city of Oaxaca, during October-November of 2000. The fields are more than 20 kilometers away from the main highway that connects Oaxaca city with Tuxtepec in the state of Veracruz. An additional grain sample was obtained from the local stores of the federal agency Diconsa which distributes subsidized food in poor localities throughout the country. Negative controls were cob samples from the Cuzco Valley in Peru and a 20-seed sample from a historical collection in the same region dating from 1971. The positive controls were provided by samples of Yieldgard *Bacillus thuringiensis* maize, and the Roundup-Ready maize, both from the Monsanto Corporation.

The study relied on a polymerase chain reaction approach and tested for a common element present in transgenic constructs currently on the market: the 35S promoter (p-35S) from the cauliflower mosaic virus, which has a widespread use in synthetic vectors used to incorporate transgenic DNA in the process of genetic modification of plants. The p-35S is not known to exist naturally in the genome of maize.

The Quist and Chapela study was able to obtain positive polymerase chain reaction amplification for the p-35S in five of the seven Mexican samples that were tested. In addition, four local landrace samples showed weak but positive polymerase chain reaction amplification. The sample from the Diconsa stores yielded very strong amplification comparable in intensity to transgenic-positive Bt1 and RR1 controls. The research report points out that low PCR

[19] France permits the import of genetically-altered corn but requires special labeling to inform consumers about the grain, developed by the Swiss group Ciba-Geigy, now part of the Swiss company Novartis, and grown in the United States.

amplification from landraces was due to low transgenic abundance from a low percentage of kernels in each cob.

Tests also showed the presence of the nopaline synthase terminator sequence (from *Agrobacterium tumefasciens*) in two of the local landraces sampled and the Diconsa sample. Because the sequences adjacent to the p-35S element were diverse, the analysis suggests that the promoter was inserted into the local landrace genome at multiple loci. The diversity of transgenic DNA constructs present in local landrace samples is an indicator of multiple introgression events that may have been mediated by pollination. Some of these events were associated with introgressed DNA that had retained its integrity as an unaltered unit. However, in other events the transgenic DNA construct seemed to have been reassorted and introduced into different genomic settings, possibly during the recombination or transformation process.

Quist and Chapela summarize some of their conclusions. First, there is a high level of gene flow from maize that has been genetically modified through the incorporation of transgenic material to populations of local landraces. This conclusion coincides with other analyses (see for example Serratos-Hernández et al 2001).

Second, the study's discovery of high rates of transgene insertion into a diversity of genomic contexts indicates that introgression events are relatively common, and that the transgenic constructs are probably maintained in the population from one generation to another. If this hypothesis is corroborated, transgenic material will be present in the DNA of local landraces, even if farmers do not seek to use transgenic corn. This is consistent with the results of a simple model of diffusion using a typical logistic function used in Serratos-Hernandez, Islas and Berthaud (2001) and in which the speed of diffusion (dispersal) of transgenic maize once it is deregulated depends on the size of the area planted to corn and the number of transgenics planted in that area. The central conclusion here is that once transgenic corn is deregulated its genetic contents will be incorporated in the genetic pool of Mexican maize germplasm.

Third, because the samples used in the study originated in remote areas, the authors conclude it is reasonable to expect that more accessible regions will be exposed to higher rates of introgression. The years 1997-1998 were not very good years in Oaxaca for corn production. Normally, if one single producer suffers from crop failure, he or she can go to their neighbors and borrow or buy the required seed stock for the next year's harvest. But, if drought or frost affect all producers alike, then the only source of seed will be other producers or a DICONSA store. For many poor growers going to DICONSA stores was the only way to replenish their original seed stock. This pattern could be repeated in any region where a crop failure event takes place and a DICONSA store happens to operate. Thus local landraces can be exposed to high rates of introgression in accessible or faraway regions alike.

As the Quist and Chapela results were subjected to peer review, two federal agencies, the National Institute of Ecology (INE) and the National Commission of Biodiversity (CONABIO) carried out their own studies on transgenic corn in Mexican fields. Although the complete studies have not been published, we know through official press releases that the research confirms the presence of transgenic material in the DNA of local landraces in localities of the states of Oaxaca and Puebla. The fields studied in localities in Oaxaca were near the area examined by Quist and Chapela, and in those samples, the new study confirmed the relatively low abundance of transgenic DNA in these areas.

The complete study has not been published, but a preliminary report was made available in March 2002. The research was initiated collecting cob samples in twenty localities in Oaxaca and two in Puebla. An additional sample of corn seeds in the DICONSA store in the town of Ixtlán de Juárez in Oaxaca. Grains were then randomly selected and sent to the Institute of Ecology (of the National Autonomous University, UNAM) and to the Center for Research and Advanced Studies (CINVESTAV). The seeds were planted and DNA was obtained for processing through PCR techniques. A total number of 800 seeds were examined to search for the 35S promoter, the *nos* terminator segment, as well as the ribosomal agent 16S used to evaluate the quality of the analysis.[20]

No evidence of transgenic sequences was found in 7 of the 22 localities included in the study. All of these seven localities are in the Sierra de Juárez in Oaxaca, not far from the area studied by Quist and Chapela. But in eleven localities (in the valley of Tehuacán, Puebla, and in the Sierra de Juárez, Oaxaca), between 3% and 13% of seeds revealed transgenic sequences. In the sample taken from the DICONSA store in Ixtlán 37% of the seeds that were planted showed positive results for 35S. Finally, in four localities in Oaxaca higher frequencies (20%-60%) of transgenic introgression were found.

According to this preliminary report, the research confirms the results of the research carried out by Quist and Chapela. These results suggest that contamination with transgenic material is not an isolated problem confined to the Sierra de Juárez, but could be a generalized to other regions in Mexico. It is important to note that the studies carried out so far focused on the 35S promoter and the *nos* terminator of the transgenic sequences. Therefore, these studies have not been able to identify the actual transgenes whose presence is indicated by the promoters and terminators. It is not yet possible to identify the exact functions (Bt toxins or herbicide resistance) of these transgenes. The study carried out by the Institute of Ecology aims to clarify this crucial point.

The preliminary data generated by this study suggests a low frequency of contaminated seeds, but, on the other hand, this takes place in a vast geographic extension. Thus, although the presence of transgenic constructs was detected in many separate fields, in the majority of these fields the frequency of contaminated plants did not dominate the traditional varieties. However, Even with these frequencies of transgene introgression confirms that these events are relatively common, and that the transgenic constructs are probably maintained in the population from one generation to another. This also corroborates the results in Serratos-Hernandez, Islas and Berthaud (2001).

The official position of the Mexican government concerning this important finding is expressed through the Intersecretarial Commission on Biodiversity and Genetically Modified Organisms (CIBIOGEM). This agency has stated that although there have been no studies proving that

[20] The 35S promoter is derived from the cauliflower mosaic virus and is commonly used as an indicator of the genetic expression of transgenes introduced into maize. The *nos* segment is derived from the nopaline synthase of *Agrobacterium tumefaciens* commonly used as an eucaryotic terminator for the RNA transcription. The Quist and Chapela study tested for the synthetic vector 35S promoter due to its widespread use during plant transformation.

genetically modified organisms through modern biotechnology harm human health, the CIBIOGEM will not liberate transgenic corn seed because of uncertainty regarding the environmental risks that may be involved. The moratorium that exists since 1998 on planting of transgenic corn does not affect scientific research. However, out of 115 projects on GMO's that had been submitted to CIBIOGEM for approval by April 2000, only two had been approved. There are currently 40,000 hectares of commercial transgenic cotton planted in Northern Mexico, and 100 hectares of experimental soy. But the CIBIOGEM has also announced that the studies required to liberate transgenic corn could take between four and six years, and during this period, CIBIOGEM plans to work with Congressional authorities to develop a regulatory framework for the application of biotechnology. CIBIOGEM also plans to undertake studies focusing on specific genes, crop characteristics, regions and ecosystems, in order to enable it to assess risks that could be involved from commercial release of transgenic crops. CIBIOGEM officials have announced that one important risk that is going to be evaluated concerns the generation of disease resistant organisms.

The International Center for the Improvement of Maize and Wheat (CIMMYT) issued an official statement concerning the results of the Quist and Chapela study. CIMMYT states that these research results are extremely important due to the fact that Mexico is the center of origin of corn. It also considers the need to evaluate the repercussions of this finding on biodiversity, the ecology in general and even in the socio-economic context.[21]

CIMMYT has also carried out its own experiments with transgenic corn, in full compliance of norms and official protocols on biosafety in Mexico. The last trial with transgenic corn sown in an open field ended in September 1999, although the CIBIOGEM had decreed a moratorium for planting of transgenic corn in mid-1998. The last CIMMYT study was allowed by Mexican authorities in order to permit CIMMYT conclude a series of studies. The study involved planting transgenic corn in CIMMYT's experimental field in Tlaltizapán, state of Morelos under the supervision of Mexican officials. A live barrier (of taller corn stalks) of at least 200 meters stood between the field with transgenic corn and the other fields, and the tassels of the transgenic plants were removed to prevent pollination of other plants. In addition, the sowing of this transgenic corn was phased out with the corn planted in the live barrier and in other fields as an extra precaution against cross pollination. The harvest was strictly controlled, the seeds transported to CIMMYT's labs, and all the remains of the plants used in the live wall were destroyed. The fields were then heavily plowed and monitored for the appearance of plants for immediate destruction. As of today, CIMMYT continues to carry out research on transgenic plants within the confines of its biotechnology laboratories and greenhouses (which have NIH level 3 protection). There is no open planting of transgenic corn by CIMMYT.

Concerned about the possible presence of transgenic material in its germplasm bank, CIMMYT screened seeds from 43 accessions of Mexican landraces. The first study was carried out in October 2001, with the screening of 28 accessions of landraces and failed to indicate the presence of the promoter CaMV 35S (from the cauliflower mosaic virus). These populations

[21] CIMMYT has been working with growers in Oaxaca for along time and has been concerned with the necessity to conserve their genetic diversity and increment their productivity. It has also analyzed the flow of genetic material between individual farmers and communities, as well as the impact of these flows on corn genetic variability and its wild relatives, teosintes and *Tripsacum*.

come from accessions collected or regenerated from eleven states in Mexico dating as far back as 1967. Although the first commercial transgenic maize was released in 1996, research teams wanted needed to check whether any transgenes had been introduced into the banks' accessions during recent regenerations of seed stocks. In November 2001, CIMMYT completed screening of 15 additional accessions of Mexican landraces and found that none carried the CaMV 35S promoter which is associated with the introduction of transgenic material.

The 43 samples include eight landraces from the state of Oaxaca and other accessions covering a broad geographic area ranging from the state of Chihuahua in the North, to Chiapas in southern Mexico.[22] CIMMYT officials also examined seeds from another set of 42 landraces from Oaxaca and collected in 2000 as part of a study on farmer varieties to check for the presence of transgenic material. These seeds are not from the gene bank accessions nor will they be added to the bank. This analysis rendered negative results as none of the examined seeds revealed the presence of CaMV 35S. If the promoter had been found, it would indicate that a transgenic maize had crossed with a maize landrace or a conventional variety at some point in the landrace's ancestry.

The CIMMYT studies on possible presence of transgenic constructs in the DNA of accessions in its germplasm bank address a real issue for concern. All accessions need to be renovated at irregular time intervals, and this is done by sowing seeds from the samples in the Center's experimental fields at El Batán, in Texcoco (east of Mexico City), Tlaltizapán, state of Morelos; and Poza Rica, state of Veracruz. Already the replacement of seeds in the bank's accessions is a critical stage in the routine operations of the bank. The variety of the original ecological conditions from which individual accessions emanate cannot be replicated in experimental stations, and this leads to a gradual transformation of the characteristics of the seed varieties stored in the bank. But, in addition, if transgenic maize is deregulated in Mexico, or if transgenic maize is sown by growers in different locations, eventually transgenic material will be incorporated into the stock of Mexican maize germplasm (Serrato et al 2001). This means that in future replacement operations of bank accessions, special precautions must be taken in order to prevent the incorporation of transgenic material into the gene bank's accessions.

Concerning the long term environmental effects of the presence of transgenes in local maize as a result of genetic flow, one of the first elements that must be considered is that the level of ignorance is rather important. The studies that are currently being carried out by INE and INIFAP are designed precisely to start bridging the gap in basic knowledge concerning, in a first instance, the magnitude of the problem we are encountering.

The key question in this regard has been aptly put by Antonio Serratos, (INIFAP biologist commissioned at CIMMYT) in the following terms: what is the evolutionary patern of a transgene in a living community, in a ecosystem?[23] Unfortunately, the state of the art of scientific information is still very weak to provide a definitive answer.

[22] The seeds were germinated and DNA extracted and amplified using a primer corresponding to the CaMV 35S promoter. The DNA isolated from a known transgenic plant harboring the CaMV 35S promoter was run as a positive control.

[23] Personal communication, January 8, 2002.

Transgenic corn may present yet other risks for Mexican landraces and for their wild relatives, the teosintes. These wild relatives are believed to have been the origin of corn. In fact, maize may have evolved rapidly from teosinte in a process involving just a few genes in ensuring this rapid transition (Culotta 1991). The individual teosinte seed is enclosed in a hard shelled fruitcase and it is dispersed naturally when the fruitcase is separated from the main body of the plant. The capacity to self-sow of this non-domesticated plant is one of the most important differences between teosinte and maize.

Today there is a collection at INIFAP's gene bank in Chapingo of 144 individual teosinte accessions, representing populations from approximately 110 sites in different regions of Mexico (Sánchez González and Ruiz Corral, 1995). Teosintes are important repositories of genetic resources and their value for future improvements of corn varieties cannot be underestimated. In certain cases, corn producers tolerate the presence of teosintes in their corn fields because it contributes to improve maize performance. In other cases, teosinte is used as green forage to feed cattle. Some farmers state that in three or four years teosintes can deliver new maize that has a better response than hybrids or even their traditional varieties. But in other cases, teosintes are perceived as weeds by growers. These two views sometimes coexist in communities that are close to each other. For example, in proximity of the Sierra de Manantlán Biosphere Reserve, growers find that teosintes have both positive and deleterious effects.[24]

Teosinte is a highly variable wild plant with both annual and perennial varieties. Naturally occurring populations of teosinte populations are present in the western slope of Mexico and Central America in a dry subtropical zone ranging from 500 meters above sea level (masl) to 1800 masl, and in Mexico's Central Plateau between 1650 to 2000 masl. There are other populations in the Valley of Mexico, Puebla and the Valley of Toluca are considered to be an anomaly (Wilkes 1995). Teosintes' growing season begins with the summer rains, runs from June to October, but by September the plants reach the mid-flowering stages, paralleling that of the local maize landraces.

Teosinte and corn can produce fertile hybrids and both plants continuously exchange genetic material in many regions of Mexico and Guatemala. In many cases, the habitats of teosinte are located in proximity or within good agricultural land. It is clear that when transgenic corn is planted, as it has been, pollen containing transgenic material will move into the germplasm of the local teosinte populations.

The risks for teosinte populations identified in the pioneering work of Rissler and Melon (1996). Transgenic corn may enhance the resistance of certain teosinte sub-populations, for example if Bt transgenes are introgressed into these plants, making them more resistant to pests. This would give one teosinte subpopulation a decided advantage and this could lead to the extinction of other subpopulations, thus reducing the diversity of teosinte varieties.

[24] One example of beneficial effects from teosinte presence in cultivated fields arises from the hard enamel cover of *Zea diploperennis*' kernels. This is why many growers like to have this wild relative of corn in their fields. Open pollination and two-way genetic flow allows for the incorporation of some traits from teosinte into maize, making it more resistant to insects that are post-harvest pests and bore tunnels into the individual kernels. Ezequiel Ezcurra, personnal communication, 1998.

The threat of extinction of teosinte subpopulations is difficult to assess. In a 1993 publication, Hernández Xolocotzi stated that teosinte populations have been negatively affected over the past 500 years by the arrival of cattle and the introduction of mechanical tillage systems (quoted by Sánchez González and Ruíz Corral 1995). These two events destroy spontaneously generated plants and make their recovery very difficult.

Wilkes (1995) proposes the use of the criteria established by the Species Survival Commission of the International Union for the Conservation of Nature (IUCN). Use of these criteria reveals that there are clear signs that certain varieties of teosinte are endangered. One example is a population in Southern Guatemala which cannot be expected to persist for long without the assistance of in situ protection mechanisms. Most of the other populations of teosinte are considered to be vulnerable, meaning that their rate of declining populations is such that if nothing is done they will become endangered. And in the case of populations thought to be rare (Nobogame, Durango and Oaxaca) they are currently under no immediate threat and are more or less stable, but they are scarce enough and could therefore be eliminated easily. There are several indeterminate populations that have been significantly depleted over the past decades, but appear to persist. They could be threatened by changes in land use patterns, especially if urban growth continues in and around eastern Mexico City. Finally, there are other stable populations, mainly in the Balsas River basin in the state of Guerrero, in Michoacán and in the state of Jalisco (Ameca). Based on observations over the last 12 years, Sánchez González and Ruiz Corral (1995) conclude that all teosinte populations in Mexico are threatened, except for those in the Balsas Basin. The risks posed by the presence of transgenic material are significant and an adequate policy response is required.

Conclusion: Some Policy Issues

The most important environmental impact of trade liberalization in corn identified so far relates to the possible loss of corn genetic variability. If a negative impact is to be avoided, welfare of corn producers that rely most on this genetic variability has to be improved. One immediate step in this direction is that the original NAFTA tariff-rate quota system for corn needs to be implemented if the undesirable environmental effects on corn genetic variability are to be avoided. But in addition, there is a clear need to recuperate the levels of investment in infrastructure, R&D and technical assistance, that were programmed at the time of the NAFTA negotiations. The concept of infrastructure needs to be extended in order to include not only dams, drainage canals, and soil management structures (terracing and use of vegetative technologies), but also social welfare constructions (sewage and municipal piping, clinics, schools, and housing). This is important to improve in the very short term living conditions. In addition, temporary employment programs should also contemplate maintenance operations on existing infrastructure that have a short-term impact on productivity. A combination of credit, crop insurance for poor producers, and technical assistance, should also be used to improve investment conditions and increase yields.

An important alternative that requires deeper analysis is to use the price mechanism to enhance welfare of these poor producers. Avoiding price distortions should be a critical guideline here, but attaining fairness is of paramount importance if environmental objectives are to be reached. One possibility is to design a mechanism through which the poorest producers that must rely on corn genetic variability could sell a predetermined amount of their crops at prices higher than those prevailing in their local or regional markets. In the case of subsistence farmers that need to replenish their stock at various intervals, purchases could be carried out at lower than market prices. Subsistence producers would be able to sell part of their stock up to a limit to be determined by identifying the average output of a class of subsistence producers in a given region. Or it could be determined through a system of certification through appropriate authorities or new institutions.

To summarize, an array of policy instruments is needed to prevent the continued deterioration of production conditions of poor corn growers. The fact that aggregate output has remained rather stable during the past six years should not be interpreted as revealing that these growers are enjoying adequate welfare levels. On the contrary, poverty continues to be pervasive among the weaker corn producers, and lack of adequate government support is aggravating their plight. Trade liberalization has had unfavorable implications for their livelihood in terms of income and wealth effects. If these trends are not reverted, the probability of losing corn genetic resources will increase over time.

References

Altieri, Miguel (1998)
“The environmental risks of transgenic crops: an agroecological assessment”. In *Proceedings of an Associated Event of the 5th Annual World Bank Conference on Environmentally and Socially Sustainable Development.* Serageldin and J.Martin Brown (eds) pp: ,Washington, DC.

INE (2000)
Estrategia nacional sobre biodiversidad de México. Instituto Nacional de Ecología (INE). México.

Gore, Charles, José Figuereido and Gerry Rodgers (1995)
“Markets, Citizenship and Social Exclusion”, in *Social Exclusion: Rhetoric, Reality and Responses*. International Labour Organization, Geneva. [1-40]

Levy, Santiago and Sweden van Wijnbergen (1995)
“Transition Problems in Economic Reform: Agriculture in the North American Free Trade Agreement”, *American Economic Review*, 85 (4). [738-754]

--- (1992)
“Maize and the Free Trade Agreement between Mexico and the United States”, The World Bank Economic Review, 6 (3). [481-502]

Larson, Bruce A. and Daniel W. Bromley (1990)
“Property Rights, Externalities and Resource Degradation”, *Journal of Development Economics*. Vol. 33. [235-262]

Louette, Dominique (1995)
"Seed Exchange Among Farmers and Gene Flow Among Maize Varieties in Traditional Agricultural Systems", in Serratos, Wilcox and Castillo (1995). [56-66]

--- and Melinda Smale (1996)
"Genetic Diversity and Maize Seed Management in a Traditional Mexican Community: Implications for *IN Situ* Conservation of Maize". Natural Resources Group (NRG) Working Paper 96-03. Mexico: CIMMYT. [21]

MacMillan, J. and P. Aquino (1996)
"Impacts on the Mexican Hybrid Maize Seed Industry: Progress Report". CIMMYT Economics Program. Mexico: CIMMYT. [7]

Mittermeier, R.A. (1988)
"Primate Diversity and the Tropical Forest: Case Studies from Brazil and Madagascar and the Importance of Megadiversity Countries", in *Biodiversity* (Wilson, E., editor). Washngton, D.C.: National Academy Press.

Nadal, Alejandro (2000)
The Environmental and Social Impacts of Economic Liberalization on Corn Production in Mexico. A study commissioned by Oxfam GB and WWF International. Geneva [108].

--- (1999)
Maize in Mexico. Some Environmental Implications for the North American Free Trade Agreement (NAFTA). Assessing Environmental Effects of the North American Free Trade Agreement (NAFTA). Commission for Environmental Cooperation (CEC). Montreal, Canada. [65-182]

Perrings, Charles (1989)
"An Optimal path to Extinction? Poverty and Resource Degradation in the Open Agrarian Economy", *Journal of Development Economics*, 30 [1-24].

Quist, David and Ignacio H. Chapela (2001)
"Transgenic DNA introgressed into traditional maize landraces in Oaxaca, Mexico", *Nature*, vol. 414 [541-543]

Ramamoorthy, T. P., Robert Bye, Antonio Lot, John Fa (1993)
Biological Diversity of Mexico: Origins and Distribution. Oxford: Oxford University Press. [812]

Rissler, Jane and Margaret Mellon (1996)
The Ecological Risks of Engineered Crops. Cambridge, Massachusetts: The MIT Press. [168]

Rzedowski, Jerzy (1993)
"Diversity and Origins of the Phanerogamic Flora of Mexico", in Ramamoorthy et al (1993). [129-144]

--- (1981)
Vegetación de México. México: Editorial Limusa. [430]

Sánchez González, José de Jesús, and José Ariel Ruiz Corral (1995)
"Teosinte Distribution in Mexico", in Serratos, Wilcox and Castillo (1995). [18-35]

Serratos-Hernández, A., Islas Gutiérrez, Fabián and Julien Berthaud (2001)
"Maize production, landraces of maize and teosinte distribution in Mexico: Elements for gene flow scenarios and risk assessment of transgenic maize release". INIFAP and Applied Biotechnology Center-CIMMYT. Mimeograph. [14].

Serratos, J. Antonio, Martha C. Wilcox and Fernando Castillo (Editors) (1995)
Gene Flow Among Maize Landraces, Improved Maize Varieties, and Teosinte: Implications for Transgenic Maize (Proceedings of a Forum). INIFAP, CIMMYT and CNBA.

Smale, Melinda, Alfonso Aguirre,
Mauricio Bellon, Jorge Mendoza and Irma Manuel Rosas (1999)
"Farmer Management of Maize Diversity in the Central Valleys of Oaxaca, Mexico: CIMMYT/INIFAP. 1998 Baseline Socioeconomic Survey". Working Paper 99-09. Mexico: CIMMYT. [26]

Toledo, Víctor Manuel and María de Jesús Ordóñez (1993)
"The Biodiversity Scenario of Mexico: A Review of Terrestrial Habitats", in Ramamoorthy *et al* (1993). [757-777]

Wilkes, Garrison (1995)
"Teosinte in Mexico: Personal Retrospective and Assessment", in Serratos, Wilcox and Castillo (1995). [10-17]