Issue Study 1. Maize in Mexico:

Some Environmental Implications of the North American Free Trade Agreement (NAFTA)

Table of Contents – Issue Study 1

List of Figures

List of Tables

Acronyms

Agroasemex	Mexican Company for Agricultural Insurance *(Compañía Mexicana de Seguro Agrícola)*
ANAGSA	Agricultural and Cattle National Insurance Company *(Aseguradora Nacional Agrícola y Ganadera)*
ANEC	National Association of Agricultural Products Trading Companies *(Asociación Nacional de Empresas Comercializadoras de Productos del Campo)*
Aserca	Support and Service to Agricultural Trading *(Apoyos y servicios a la comercialización agropecuaria)*
CIMMYT	International Center for the Improvement of Maize and Wheat *(Centro Internacional de Mejoramiento de Maíz y Trigo)*
Cinvestav	Center for Research and Advanced Studies
CNG	Mexican national Livestock Council *(Consejo Nacional Ganadero)*
Conasupo	National Corporation for the Sustenance of the Population *(Compañía Nacional de Subsistencia Populares)*
ENE	National Employment Surveys *(Estadísticas Nacionales del Empleo)*
FAO	United Nations Food and Agriculture Organization
FDI	Foreign Direct Investment
FIDA	Fund for International Agricultural Development *(Fondo Internacional de Desarrollo Agrícola)*
GATT	General Agreement on Tariffs and Trade
GNG	Mexican National Livestock Council
INE	National Institute of Ecology *(Instituto Nacional de Ecología)*
INEGI	National Institute of Statistics, Geography and Informatics *(Instituto Nacional de Estadística, Geografía e Informática)*
INIFAP	National Institute of Forestry and Agricultural Research *(Instituto Nacional de Investigaciones Forestales y Agropecuarias)*
IPM	Integrated Pest Management
NAFTA	North American Free Trade Agreement
NP	new pesos
NWC/CNA	National Water Commission *(Comisión Nacional del Agua)*
OECD	Organization for Economic Cooperation and Development
Procampo	Agriculture Support Program *(Programa de Apoyo al Campo)*
Pronase	National Seed Company *(Productora Nacional de Semillas)*
Pronasol	National Solidarity Program *(Programa Nacional de Solidaridad)*
Sagar	Secretariat of Agriculture *(Secretaría de Agricultura y Ganadería)*
Secofi	Secretariat of Trade and Industrial Promotion *(Secretaría de Comercio y Fomento Industrial)*
Sedesol	Mexican Social Development Secretariat *(Secretaría de Desarrollo Social)*
TRIP	Trade Related Intellectual Property
UNAM	Autonomous National University of Mexico *(Universidad Nacional Autónoma de México)*
UPOV	International Union for the Protection of Plant Varieties
WRI	World Resources Institute

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Executive Summary

The purpose of this study is to consider the environmental implications of expanded North American trade and investment under NAFTA by implementing and developing a general framework being constructed by the Commission for Environmental Cooperation's NAFTA Effects Project.[1] Corn is produced in Mexico by a wide variety of producers operating under diverse agro-ecological conditions, using a broad range of technologies and with varying environmental impacts. This study focuses on several closely-linked sets of issues which relate the effects on relevant environmental dimensions arising from the behaviour of corn producers in response to economic and social forces unleashed or sustained by NAFTA.

There is evidence that corn originated in central and western Mexico more than 7,000 years ago. Today, maize is a staple in the country's diet and there are 25 different varieties recognized in Mexico. Mexican maizes have been important in the development of modern high yield varieties. Corn is well adapted to a wide range of different climatic and soil conditions. It is cultivated in latitudes varying from the equator to more than 50 degrees and in altitudes between sea level and 4,000 meters. It is cultivated in both fully irrigated land, as well as in semi-arid conditions, and the growing cycles may extend from 3 to 12 months. World corn production averages 450 million tons—a quarter of global grain production. Maize is an important commodity in international trade, and it is expected that demand will continue to expand.

Production of white corn in Mexico represents 63 percent and 66 percent of total agricultural output in volume and value terms, respectively. It also occupies 62 percent of total cultivated surface. It is estimated that 2.5 to 3 million producers are directly engaged in the production of white corn in Mexico. Considering the average size of rural households, up to 18 million persons depend on the production of corn for their livelihood.

The potential environmental consequences of trade liberalization involve a complex set of issues, although the relationship between corn and NAFTA is direct. Chapter VII of NAFTA provided for an immediate conversion of the corn tariff system into a tariff-rate quota system to be phased out over fifteen years. An immediate tariff-free quota of 2.5 million metric tons of corn was granted by Mexico. The tariff-free quota is to expand at a compound rate of 3 percent per annum beginning in 1995. Nevertheless, duty-free imports of corn from the United States have exceeded NAFTA's import quota. At the same time, domestic prices have dropped to international levels. Despite this, total production of corn in Mexico has remained the same and in some cases has increased.

Patterns of production and social activity are two processes through which responses to declining prices could be felt. Income for producers may originate in off-farm activities as well as from the direct sale of agricultural products. Thus, falling prices can affect real wages as the price of corn drops. Because the household is often the critical unit of analysis, different options for the allocation of available labor are an important component of decisions to adopt different

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[1] Some studies undertaken prior to NAFTA attempted to estimate the direction and magnitude of its prospective effects on corn producers. A review of some of these studies is attached to this report as Appendix A.

production strategies. This is particularly true where household members need to enter local, regional, national or international labor markets through migration. Migration does not necessarily mean the complete abandonment of corn production, but it may contribute to the weakening or deterioration of social institutions that, in many cases, support systems of production. Migration is closely related to the production strategies of traditional corn producers.

As the different groups of corn producers adjust to the dynamics of changing prices, their strategies may have important environmental effects. This study points to three principal production responses open to Mexican corn producers. Each set comprises an array of possible technological choices regarding input and output mixes that could constitute key linkages to the environment. Not all of these strategies are open to all categories of producers and in some cases producers may resort to combinations of the different strategies. These strategies, which may affect the environment in different ways, are as follows:

1. One production response is aimed at modernizing corn production to meet the challenges posed by imports.
2. A second production response involves the substitution of corn by other crops, either in the basic grains sector or in other sectors including horticulture, forestry or livestock.
3. A third production response is to continue to produce corn in a traditional manner for self-consumption.

The following paragraphs highlight key issues associated with changing production strategies.

Modernization to meet the challenge of imports

The modernization of production technologies and techniques is an option available to an important group of producers operating under both irrigated and rain-fed conditions. In general, modernization involves the adoption and diffusion of capital-intensive production technologies and techniques including irrigated systems (or very good and reliable rain-fed conditions), the use of hybrid and open-pollinated improved varieties (OPVs), the intensive use of agro-chemicals (fertilizers and pesticides) and the heavy use of mechanized traction.

Most of the improved seeds used in modernization efforts are hybrids produced in Mexico by private companies. These seeds tend to produce yields that are comparable to US yields and, within the present price structure, they ensure profitability. Several categories of producers in Mexico today already have access to these technologies or have the option to modernize and upgrade their productive capacity in order to compete with corn imports.

The environmental implications of such changes in production are varied. First, much of this technology necessitates the intensive use of water resources. Second, soil quality may be affected by residue from pesticides and fertilizer,[2] or from the intensive use of irrigation where inefficient drainage systems can result in the salinization of soils. Third, soil quality may be affected by the more intense tillage that can accompany modernization. Where production occurs on sloping lands the loss of topsoil and erosion can be further aggravated. The effects of soil degradation upon yields may be compensated for by a more intensive use of fertilizers. Fourth, modern production techniques are best suited to the use of high-yield varieties and hybrid seeds. The generalized and intensive use of high-yield seeds has been shown to lead to losses of landraces and wild relatives, causing genetic erosion.

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[2] The elimination of subsidies for the purchase of chemical inputs may encourage producers to adopt a more rational use of these inputs.

On the other hand, modernization can also take place through minimum- or no-tillage cultivation. This practice is expanding in many areas and entails significant savings in energy costs by reducing reliance on tractors. Indeed, it has been reported that when no-tillage methods are used the energy input into corn production is reduced by 7 percent with yields as high or higher than with conventional plowing and disking methods.[3] Minimum or no-tillage techniques also reduce and in some cases can eliminate soil erosion. However, they can involve the increased use of pesticides that could affect the quality of the soil, surface water and aquifers. When secondary tillage for weeding purposes is eliminated, coverture is left behind to rot at the end of the harvest and more herbicides are required. This process is aggravated on irrigated land where the coverture can impede the free flow of water through the furrows in a plowed field. In order to combat this problem and avoid wasting scarce water resources, additional labor may be required.

Some practices such as intercropping or crop rotation, the use of cover crops (left to rot on the field as mulch), or the use of organic fertilizers, are on-the-shelf techniques available to almost all producers. However, some may not be easy to implement or may be out of reach given the resources required to introduce them. In the case of the modern technologies, the capital and information requirements they involve put them out of reach of a large number of producers. For example, it is likely that biotechnologies and their increasing diffusion will dominate the direction of technical changes in agriculture in the future. Whether the contribution of these biotechnologies can be harnessed for a more environmentally sound system of agricultural production, or whether they will aggravate trends towards the increased use of synthetic inputs, is an open question. In some cases, their commercial application in the short term may reduce environmental stress (less chemical inputs to combat insect pests) or may improve product quality (such as enhanced protein content). In other cases, crops could be bioengineered to withstand greater doses of pesticides (particularly herbicides).

Most biotechnology will be incorporated into improved germplasm (seeds). No significant changes in production and management practices will occur and most of these applications will not have a significant impact on yield. Yield-enhancing biotechnologies will have to await the capability to transfer complex configurations of genes. Although some biotechnologies have the potential for reducing the use of agricultural chemicals, more information is needed regarding the components of the technology package. The experience of the “Green Revolution” shows that the more capital-intensive technological breakthroughs may have detrimental social and economic side effects as well as increasing environmental stress.

The modernization of corn production is most readily available to producers who already work with a number of these technologies in regions such as El Bajío in central Mexico, Jalisco, parts of Tamaulipas, southern Nayarit and the states of Sinaloa and Sonora. It is also an option for producers in other parts of Mexico operating in conditions that include well-drained and good quality soils, irrigation or fine rain-fed systems, and access to the institutional infrastructures required by modern production such as credit, marketing channels and technical assistance.

Substitution of Corn and Changes in Land-Use Patterns

Crop substitution in order to take advantage of the changing structure of relative prices for the sub-set of agricultural products is a second option open to corn producers. This includes the shift from corn production to other basic grains (in particular feed grains) as well as to horticulture and fruits. Some suggest that more labor-intensive crops represent the segment of agricultural production where Mexico has a comparative advantage (Levy and van Wijnbergen 1992, 1995).

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[3] Raven et al. (1992,701) estimate that, given the rates of diffusion of this technology, by the year 2000 approximately 65 percent of the acreage of crops grown in the United States may be grown under no tillage conditions.

Producers may also change their land-use patterns by allocating more land for pasture and forest plantations or by increasing their fallow period. The conversion of cropland to pasture and forest plantations could have important environmental implications. Both long-term crop substitution and changes in patterns of land-use can lead to the loss of genetic diversity if the process occurs in regions where landraces are being used.

On the other hand, a shift from corn production to the production of other grains (particularly feed grains such as sorghum or barley) may have positive environmental effects. In some cases, such as with some fine-grain crops that do not require row cultivation, plowing might be reduced, or minimum- or no-tillage practices might be introduced. Some crops such as sorghum require less water per unit of output than corn.

The capital and technology requirements for diversification into high-value horticultural crops do not make them easily accessible to all producers. It is estimated that production costs in horticulture are between five and seven times those of maize production (FIDA 1993,93), and there is some evidence that social and economic inequalities are enhanced by the expansion of these crops (Thrupp 1995,70). There is also growing evidence that the production of some non-traditional export crops involves environmental costs including more intensive use of inputs such as water and agro-chemicals and extending to issues of human health associated with agricultural workers and other exposed populations.[4] In addition, the generalized use of pesticides of all types can lead to the development of resistance in pests necessitating the introduction or increased use of new pesticides. Integrated pest management is an important option in this context as is the greater reliance on organic methods of production such as those already introduced in crops such as coffee and cacao.

In some cases, land once used for the production of corn might be converted to grazing pasture or forest. Environmental effects of this change in land use include the possibility of soil erosion from over-grazing or losses of landraces and wild relatives of corn varieties particularly where single-species plantations are developed or where foreign species are introduced. However, some changes in land-use patterns may have positive environmental effects where, for example, marginal lands previously used for corn production and transformed into tree plantations.

Traditional Methods/Subsistence Producers

For a segment of corn producers, modernization or crop substitution may not be available options, while at the same time, abandoning corn production may be impossible. This segment is made up of subsistence farmers[5] or of traditional producers who sell into the market but whose profitability is extremely low. The main option open to these producers is to maintain the production of corn in combination with a greater reliance on off-farm income sources.

In some cases, producers may migrate to local, regional or even international centers where employment may be obtained in order to compensate for the loss of income associated with abandoning or decreasing corn production. In these cases, when the demographic structure is transformed and the supply of labor diminishes in communities that generate emigration, reliance on labor-intensive technologies can be affected and the quality of the remaining labor supply can be diminished. This process could have a range of environmental effects, including the inadequate maintenance of structures designed to reduce soil degradation, husbandry, seed selection and preservation, and other aspects of agricultural production.

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[4] For a comprehensive analysis see Thrupp (1995).

[5] In the case of subsistence farmers, immediate cash needs are met through petty sales of corn, which has been stocked from the previous harvest. This process blurs the distinction between subsistence producers in a strict sense and small producers who also sell in the marketplace.

The household strategy of subsistence farmers may also rely on other methods of generating income including raising sheep and goats, which can increase pressure on land as overgrazing may eliminate soil cover, and vulnerability to erosion from rainfall is increased. In some cases, lengthening fallow periods for land may be the result of this strategy in which the household relies more heavily on off-farm sources of income that are not dependent on its ability to produce and sell corn. The effects can be positive for marginal lands left to rest if overgrazing is avoided.

If the segment of the corn-producing sector which sells into regional or local markets is displaced by imports and if entry to the horticulture sector is not possible, rural employment opportunities may diminish. This may result in the household exerting more pressure on resources such as land.

This study indicates that changing production processes, technologies, social organization and environmental impacts are all tightly related and interdependent. Environmental impacts generally include, among others, the effects of agrochemical inputs such as pesticides and fertilizers, which can be carried through surface and groundwater and the atmosphere. The two areas that stand out as critical in this analysis are soil quality—long-term soil fertility, loss of topsoil, and erosion—and the stock of genetic resources.

With regard to soil quality, the loss of topsoil, different degrees of erosion, fertility reduction, salinization and the accumulation of agrochemical residues are important issues. Erosion from water and wind affect a significant proportion of Mexico's arable land. NAFTA is not responsible for generating erosion. However, forces unleashed by the NAFTA regime for corn could be a factor that contributes to accelerating these trends, particularly in regions where modernized corn production exists. Between 1990 and 1995, official data show that there has been a trend to expand cultivated surface while yields per hectare are reduced, suggesting use of marginal land.

Genetic diversity in Mexico is the second key environmental dimension of this study. Nowhere in the world is the spectrum of variation of maize as great as it is in Mexico, and nowhere is it as deeply entwined with the social and economic life of the people. Mexican germplasm can be found in many corn varieties throughout the developing world and its importance should not be underestimated.

Mexican producers using traditional technologies for corn in the rain-fed cycle rely heavily on genetic diversity in their survival strategies by sowing different varieties of corn seeds. These varieties are negatively correlated to changes in precipitation, humidity, weather patterns, pests, winds, low nitrogen or acid soils. Their combined use and association with other crops offers some degree of harvest insurance in the face of uncertainty.

Related production decisions involve significant informational requirements regarding relations between seed characteristics, soils, climate, topographic features and pest risks. This information has been transmitted orally from generation to generation. If there are economic pressures on the populations relying on these strategies that force them to migrate or to sell their labor to other producers, or to engage in off-farm activities, this information will be gradually lost, representing a social contribution to genetic erosion.

Genetic erosion through social processes has been underway since well before NAFTA but again, although this study indicates that processes related to changes in the corn sector could affect these processes. Genetic erosion through high-yield seed varieties (HYVs) has not been widespread, a HYVs have not traditionally been able to compete with local landraces in regions where producers rely on diverse corn varieties as part of their survival strategies. This is due to the heterogeneous conditions of soil quality, water and climate regimes, local pests and other variables, which negatively affect HYV performance. Thus, the most significant threat to genetic diversity comes from social organization.

However, a further threat to genetic diversity could be the modernization of corn production through the use of transgenic crops, which are developed through genetic engineering techniques. These techniques do not create new genetic information, they can only manipulate the existing material. Many new bioengineered corn seeds have already appeared in the US market, and they will eventually be used by Mexico's modern corn producers. In Mexico there are signs that alien genetic material may flow from the bioengineered plants to corn's most important wild relatives, *teosinte* and *tripsacum*. Over time, this transfer of genetic material could lead to the extinction of *teosinte* subpopulations whose genetic structure is valuable and can enhance resistance to heat stress, drought, waterlogging, foliar diseases and pests.

The following matrix highlights some of the linkages between some production choices and the environment. It is neither a substitute nor a comprehensive summary of the contents of the analysis and it cannot capture the dynamics of the process or the manner in which the different responses are interrelated.

The first column lists the three major and other important possible production responses of corn producers and the four columns that follow present some environmental dimensions associated with those decisions. The broad set of changing economic strategies can be accompanied by a complex set of technical changes related to the different phases of production.[6] These technical changes could include the more efficient use of water resources, more rational use of chemical inputs, and better practices for the conservation of soil qualities (such as live-wall terracing and alley cultivation or minimum-tillage practices). They may also include a reduction in the use of chemical pesticides (such as integrated pest management systems). But they could also involve greater environmental stress.

Although these technical alternatives may be readily available, they may or may not be feasible options depending on their particular input combinations and changes in relative prices. In some cases producers may continue to rely on traditional technologies with little or no modification. This applies to modern capital-intensive producers as well as to traditional corn producers, where there are some signs that the technological base is deteriorating.

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[6] Some of the changes identified in this paragraph are related to technologies that have existed for several decades.

Matrix of Changes in Productive Strategies and Linkages to the Environment

Responses	Environmental Consequences			
	Soils	Water	Agrochemicals	Genetic Resources
Modernization of Corn Production	More intense tillage in sloping land can increase erosion. Conservation techniques available: no-tillage, vegetative techniques.	Increased water use but also potential for more efficient use of water (drip irrigation, higher end use efficiency).	Greater use of agrochemical inputs in modern technologies. Negative effects on workers' health; accumulation of residues. No tillage implies greater use of pesticides, IPM[1] a possibility.	Some genetic erosion (GE) possible, but most GE due to hybrids/OPVs already has taken place.
Persistence of Corn Production with Traditional Methods	Extensive use of low quality or marginal lands encourages erosion. Most of this production in regions with greater precipitation.	Most of this type of corn production is rain fed. Under economic pressure little or no resources devoted to improved water use.	Some use of fertilizers and pesticides. Reduction of rates of use as prices increase	Greatest potential for GE if group of poor producers disappears or continues to function under economic stress. Loss of genetic resources has begun.
Crop Substitution (Horticulture, Other Grains)	Risk of erosion may increase where crops require more intense tillage and harrowing, particularly on sloping land.	Most horticulture crops are more water-intensive. Some grains (sorghum) are less water-intensive. In capital-intensive processes some potential for more efficient use of water resources exists.	Most horticulture crops are more intensive in agrochemicals. Risks of residue accumulation. Negative effects on workers' health serious risk.	In some regions GE may occur but probably most of GE of this type has already taken place.
Land Use Changes (Livestock, Tree Plantations)	Reduces risk of erosion on marginal lands unless overgrazing occurs.	Most of these changes in land use patterns under rain fed conditions.	Some use of agrochemicals but not intensive enough to pose a serious threat to environment.	Monoculture patterns threaten biodiversity.
Reallocation of Household Resources and Changes in Social Organization	Longer fallow periods reduce erosion but could be reversed by overgrazing. Migration reduces households'[2] and communities' capacity to maintain land conservation infrastructure.	Migration reduces supply of highly qualified labor and may reduce capacity to improve use of water resources.		Disruption of social organization affects capacity to maintain adequate management of genetic resources.

[1] IPM, Integrated Pest Management

[2] Not included in this matrix are important human environment implications derived from changes in nutritional properties of tortillas made with dough from industrialized maize flour instead of homogenized or *nixtamal* dough. Another item not shown here but covered in the study is related to energy consumption patterns. Modernized corn production is more energy intensive, but aggregate levels of energy consumption in Mexican corn production are very low.

I. Introduction

The purpose of this study is to consider the environmental implications of expanded North American trade and investment under NAFTA by implementing a general framework developed by the Commission for Environmental Cooperation's NAFTA Effects Project. The scope is sectoral, focusing on white corn *(Zea mays)* production in Mexico. Other varieties (such as yellow and purple varieties) will be included in the analysis in so far as they affect the dynamics of white corn production.

Maize is the main staple food in Mexico's diet. In 1996 the production of white corn in Mexico represented 63 percent in volume and 66 percent in value of total Mexican agricultural output. It is estimated that 2.5 to 3 million producers are directly engaged in the production of white corn in Mexico. Based on the average size of rural households, between 15 and 18 million persons may depend on the production of corn for their livelihood.

World production of corn averages 450 million metric tons—a quarter of global grain production. Maize is a very important commodity in international trade and it is expected that demand will continue to grow. The importance of corn in Mexico should not be underestimated. Evidence shows that *Zea mays* originated in central and western Mexico more than 7,000 years ago. There are now 41 different races and several thousand varieties recognized in Mexico, making it the global center of genetic diversity for maize. Indeed, Mexican maize plays an important role in the development of modern improved open-pollinated and hybrid high-yield varieties of corn that are instrumental in maintaining the world's food supply.

Trade liberalization and processes that flow from it have had an impact on the corn sector in Mexico. This sector has immediate and widespread effects on many dimensions of the air, water, land and biota that make up North America's ambient environment. This issue study helps develop the general framework by uncovering effects on these environmental dimensions primarily because it looks at changing patterns of government policy, production, technologies and social organization that are not addressed in such detail in the other issue studies.

The analysis focuses on a number of agricultural practices that have been available for quite some time, such as crop rotation, intercropping or contour plowing, and which may or may not be adopted by corn producers. It seeks to determine the extent to which these environmentally sound practices will become generalized or abandoned as trade liberalization proceeds. In addition, the study strives to analyze the implications of innovations in agricultural processes in so far as they relate to corn production. The favorable potential of practices such as minimum- or no-tillage, organic pest control, water conservation technologies or some of the emerging biotechnologies is examined in relation to the issues raised in the analysis. The research also seeks to analyze the effects of technology and investment flows that may mitigate existing issues or prevent new ones from arising.

The major arguments in this study follow the NAFTA Effects General Framework (Phase II). Section II provides the environmental, economic, social and geographic context for the issue. Section III describes the major NAFTA rule and institutional changes affecting the corn sector. It then discusses the trade flows in the sector. While other economic forces have been important, the impact of NAFTA in this sector has been discernable. Section IV takes up the main linkages from these changing patterns of trade to the natural environment through production, management and technology, physical infrastructure, social organization and government policy. This section focuses on trends in corn producers' responses to changing economic signals, including those flowing from government policy. It underlines the relation between these changing economic strategies and the technological and agro-ecological conditions under which the market operates. It also examines in some detail the critical linkage of "social organization" with an emphasis on the consequences of migration and the reallocation of resources at the community and household levels. Section V then examines the environmental stresses associated with the production and social trends identified. These environmental stresses are related to the technology used in corn production and are primarily linked to soil management and genetic resources.

II. The Issue in Context:

Environmental, Economic, Social and Geographic Conditions

A. The Environmental Context

Due to its sheer size, maize production has a major impact on the environment in Mexico as a whole. In 1996, corn was grown on 62 percent of the total cultivated land in Mexico—the largest percent of cultivated land dedicated to one crop. This section identifies environmental issues related to agriculture in general and corn in particular and they are not presented as effects of processes related to NAFTA. The linkages between corn production and the natural environment are numerous and complex. They include, among others, the effects of agrochemical inputs such as pesticides and fertilizers—which can be carried through surface water and groundwater and the atmosphere—long-term soil fertility; loss of topsoil and erosion; and the stock of genetic resources.

1. Air

Agrochemicals, such as pesticides, can pose risks to human, animal and plant health, particularly if used inappropriately. From a human health perspective, recent research indicates that the effects of exposure are particularly damaging to the immune system, diminishing the capacity of individuals to endure or avoid infectious and parasitic diseases (Repetto and Baliga 1996). Their effects are not limited to populations that are directly exposed because they can be transmitted long distances through the atmosphere, enter hydrological cycles, and accumulate in soil.

The use of agrochemicals for corn production in Mexico varies significantly between regions. The first way pesticides affect air quality and, through it, other environmental media, is by airborne spraying. The application of pesticides is generally carried out using one of three methods: the spraying of fields by low-altitude aircraft, by tractor-drawn rigs, or by sprayers carried by individual workers.

Application by low-flying aircraft can expose large human populations most seriously.[7] Exposure to pesticides is important for populations living close to agricultural fields. On-the-job exposure can also be high with the application of pesticides by individual workers carrying backpack sprayers when appropriate protective clothing is not available or properly used.

There is no reliable information available on spraying techniques of pesticides in corn production in Mexico. The costs associated with air spraying make this method available only to the wealthiest producers. In some cases it is most

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[7] For example, in the Culiacán valley, this method of application is common and the population in neighboring fields is estimated at 200,000 people. Under normal conditions, drift can be minimized to 10 percent of the sprayed pesticide. But under adverse conditions, the drift can reach levels as high as 95 percent (Wright 1990) causing waste, pollution, and posing a health hazard.

effective to use granular insecticide formulations placed directly in a plant's whorl. This transforms pesticide application into a labor-intensive task where spraying is best performed on foot directly on the affected or vulnerable parts of the plant. This type of application is the most effective to combat pests that attack corn in Mexico.[8] Application requires targeting by spraying, using crews of workers walking through rows of crops, thereby maximizing the effects of the chemicals but exposing workers to toxic pesticides.

Impacts depend on the particular pesticide employed. The Ministry of Agriculture in Mexico recommends a series of pesticides for use in corn production, although some are considered dangerous by the Health Ministry (Alatorre 1997). In the Culiacán and San Quintín valleys (in Sinaloa and Baja California states respectively) nonpersistent pesticides[9] are predominant. Although these chemicals have shorter half-lives in general they are more toxic than persistent pesticides.[10]

A second way corn production can affect air quality is through energy use. Table 1 provides data on the consumption of energy in the agricultural sector as a whole, compared with other economic sectors in Mexico. These data show that agriculture in Mexico is a relatively low consumer of energy compared to other major sectors and that between 1988 and 1995 energy consumption in agriculture dropped, suggesting the relatively depressed state of that sector during those years. In addition, this aggregate information does not accurately reflect energy consumption by households using fuel wood for domestic purposes.

Table 1 Energy Consumption by Economic Sector

Energy Consumption (Petacalories/year)

Sector	1988	% of Total	1995	% of Total
Agriculture (includes livestock)	25.554	3.0	23.562	2.4
Residential, commerce and public	174.950	20.5	202.482	20.6
Transportation	269.565	31.6	353.639	35.9
Industry and mining	269.007	31.3	328.345	33.4
Petrochemical, PEMEX*	88.789	10.4	64.679	6.6
Other sectors	26.132	3.1	11.063	1.1
Total	851.997	100.0	983.770	100.0

Relative Energy Consumption (Petacalories per billion pesos of sectoral GDP)

Sector	1995
Agriculture (includes livestock)	0.318
Residential, commerce and public	0.313
Transportation	3.184
Industry and mining	1.096
Total Mexican economy (petacalories per billion pesos of GDP)	0.799

* PEMEX: *Petróleos Mexicanos*

Source: El sector energético de México, *INEGI 1994. Balance Nacional. Energía 1995. Sec. de Energía 1997. Informe de Gobierno 1997. E. Zedillo.*

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[8] In cases such as the southwestern corn borer *(Diatraea grandiosella)* or the fall armyworm *(Spodoptera frugiperda)* targeting is more important than in other cases (Ortega 1987). During some of their vital stages, the larvae of these insects can lodge inside a plant's stalk or penetrate deep inside the whorl.

[9] Such as organophosphates including *parathion*, *methamidophos*, *guthion*, *malathion;* carbamates such as *aldicarb;* and chlorinated hydrocarbon insecticides such as *endosulfan*.

[10] Nonpersistents replaced persistent varieties because the latter may accumulate once they are released into the environment and remain there for years (or even decades). Thus they may also accumulate through the trophic linkages in certain species, causing chronic diseases and reproductive disturbances. Persistents (such as DDT) are less likely to cause immediate negative health effects from quantities found in agricultural fields. But their longer half-lives make them particularly difficult to control. Nonpersistent pesticides are more acutely toxic to human and animal health. In comparison with the most commonly used persistent insecticide (DDT), the most commonly used nonpersistent (parathion) poses a greater immediate threat to mixers, applicators, field workers and rural residents. (Wright 1990).

2. Water

Maize production also has a major impact on the use of water resources. Agriculture and livestock production is carried out on approximately 46.5 million hectares, of which 27 million are used in extensive livestock production and 19.5 are used in cultivated agriculture. Of the cultivated land, approximately 5.4 million hectares is irrigated. Irrigation provides the basis for all export-oriented crops and includes wheat, alfalfa, soybean, cotton and horticulture (Turrent 1997). Twenty-six percent of total production of maize is undertaken on irrigated land. This represents 13 percent of the total land in Mexico devoted to corn production (Table 2). Nevertheless, given the volume of maize produced in Mexico, it is the most important irrigated crop. The remaining 74 percent of production is undertaken in rain-fed systems.

Rainfall provides 85 percent of the water used in Mexico and underground aquifers make up the remaining 15 percent. Mexico receives 1,530 cubic kilometers of water each year in rainfall (see Figure 1). Approximately 27 percent of this water drains back into the oceans through Mexico's river systems. Hydraulic infrastructure (for all uses, including agriculture) captures 9.6 percent of the total rainfall. As of 1980, there were 31 cubic kilometers of underground renewable water bodies, and an additional 110 cubic kilometers of fossil underground water.[11]

Table 2 Share of Main Crops Cultivated Using Irrigation Systems

Crop	Harvested Surfaces[1] under Irrigation	Rain-fed	% Production Obtained from Irrigated Surfaces
Maize	1,008	6,703	26
Wheat	841	264	89
Sorghum	581	1,091	49
Beans	274	1,927	33
Alfalfa	262	8	96
Soya	252	64	87
Sugarcane	244	399	42
Cotton	185	33	91
Horticulture	N.A.	N.A.	80

[1] Thousand hectares.

Source: FIDA (1993) with data from SARH and National Water Commission.

The National Water Commission (NWC) estimates that aquifers receive approximately 31 billion cubic meters of water every year. This compares favorably with the 26 billion cubic meters withdrawn every year for all uses. Thus, at the national level aquifers are being replenished even if locally or regionally some are overexploited.

The distribution of water throughout the country is irregular. Sixty-three percent of Mexico's total water resources run through only eight states.[12] Hydraulic infrastructure for irrigation is concentrated in the states that account for 37 percent of total rainfall. Irrigated land for cultivation is concentrated in the northern and central Pacific coast of Mexico, and in central Mexico. These two regions contain more than 80 percent of irrigated land, more than 70 percent of Mexico's population and 19 percent of total rainfall.

Total annual water consumption in Mexico exceeds 171.5 billion cubic meters. Table 3 indicates the distribution of this consumption. Irrigated agriculture is second only to hydroelectricity in its total water use, accounting for over one third of Mexico's total consumption.

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[11] At this point in time, 73 percent of Mexico's territory had been effectively explored for groundwater resources.

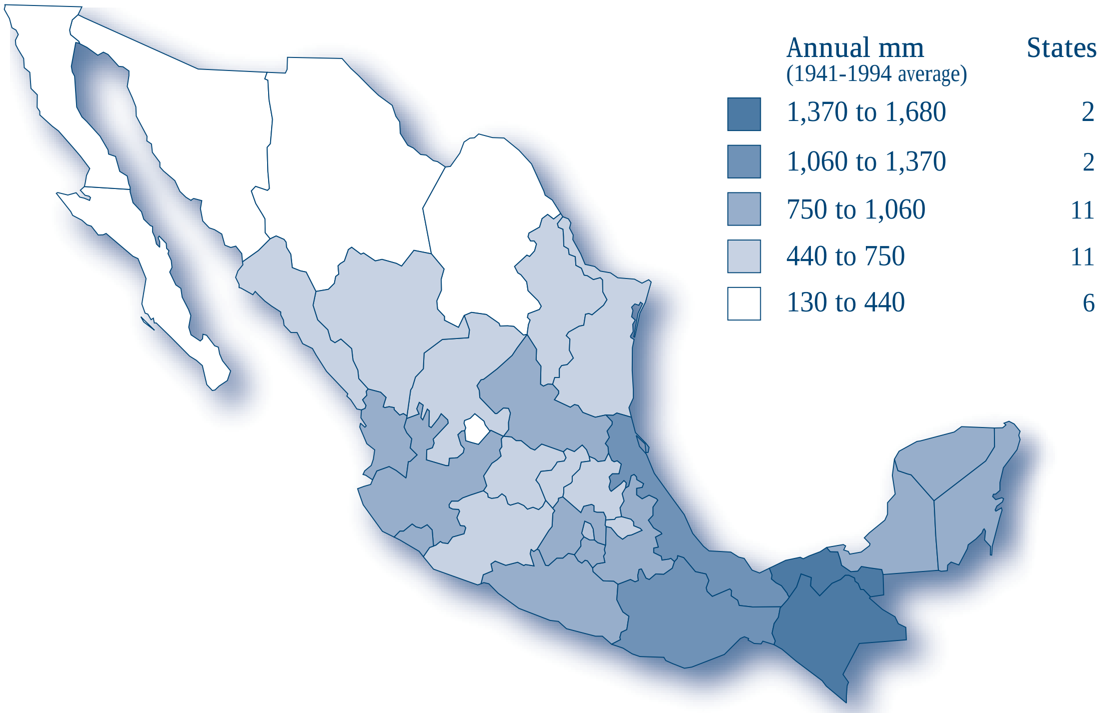
[12] Veracruz, Tabasco, Campeche, Yucatán, Quintana Roo, Chiapas, Oaxaca and Guerrero.

Table 3 Distribution of Total Water Consumption in Mexico

Water Use	Cubic meters (billions)	Percentage
Hydroelectric energy	92.6	54
Agricultural irrigation	65.1	38
Industrial uses	5.1	3
Domestic uses	8.5	5

Source: Turrent (1997).

Figure 1 Annual Precipitation



Source: Environmental Statistics, INEGI.

Data from the NWC in 1990 (in FIDA 1993) indicate that out of a total of 294 hydrological zones, 197 are overexploited. Thus, 67 percent of aquifers are not being replenished at the same rate at which they are being depleted. The situation is particularly acute in Mexico's northern and central states with high population densities and where irrigated corn production is concentrated.[13] Underground aquifers also suffer from increasing pollution, as do surface water bodies.

3. Land

Soil quality and the loss of topsoil are important issues associated with agriculture generally and corn specifically. In Mexico, it is estimated that over 70 percent of total arable land is affected to some degree by erosion caused by water

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[13] As well, the mean depth of wells has been increasing. The current average depth of wells is 66 meters compared with an average of between 15 and 20 meters in the 1940s and 40 meters in the 1970s.

or wind. Much of Mexico's agriculture takes place on sloping land using conventional tillage practices that are not directed towards conserving soil or preventing its erosion.

Rain-induced erosion is most prevalent in the southern tropical regions of Mexico because more intense precipitation coincides with steeper slopes and runoff is greater. In the semi-arid north there is less precipitation and less runoff but also less vegetative cover and shallower soil. The ability to arrest erosion by introducing cultivation practices that slow or prevent loss of topsoil is of critical importance.

Statistics are available for three different levels of erosion intensities in Mexico, but the degree of resolution provided by this information is crude.[14] Nevertheless, sufficient information exists, as indicated in Table 4, to determine that in some cases erosion is serious and has been underway for years.

Studies suggest that erosion rates in many regions in Mexico are higher than soil formation rates.[15] For example, one study on slopes under corn cultivation in the Los Tuxtlas region in Veracruz state reveals that loss of soil reaches 43 metric tons per hectare per year—two or three times greater than the soil formation rate (Turrent 1997). In northern Veracruz, rates of loss have been recorded as high as 100 metric tons per hectare per year (ibid).[16]

Soil features affect nutrient formation and retention.[17] On flat surfaces under rain-fed cultivation, the main problem is loss of the arable segment of the "A horizon" (containing the concentration of organic material) and the formation of scabs (compact blocks of soil with irregular sizes and shapes). This process contributes to a decrease in soil productivity, and the costs associated with arresting it and redressing the damage are great.

On flat surfaces under irrigation, the main problem is salinization due to evapotranspiration. It is currently estimated that at least 560,000 hectares of irrigated land (around 10 percent of all land under irrigation) is affected by salinization. When plants can no longer tolerate levels of salinization that land must be abandoned. This problem can be mitigated if salts are flushed to lower soil levels through increased water use, although this is not practical where water is scarce. Technology and infrastructure to provide for efficient draining of salts can be incorporated into irrigation systems, although the high cost of these systems have hampered their development and use (Turrent 1997).

Acidification is another issue associated with soil quality in Mexican agriculture. Acidification arises from the use of ammonium sulfate as a source of nitrogen in soils with low activity-level clays and low-base status.

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[14] A nationwide map of geomorphologic risks is under preparation at the Institute of Geography, National Autonomous University of Mexico. Some aggregate figures are available and isolated studies focusing on certain localities exist with specific measurements of erosion rates or losses of topsoil.

[15] Indirect indicators of loss of topsoil can be identified in siltage of dams and drainage and irrigation canals.

[16] Soil erosion rates of this magnitude may exceed soil formation rates by an even greater proportion if soil formation rates are slower. According to Pimentel, Allen et al. (1993, 278) in most of the worlds' major agricultural regions, soil formation rates are 1 t/ha/yr. A study in the La Fraylesca region in the state of Chiapas indicates that under conditions of conventional tillage for corn cultivation erosion rates exceed the permissible limits for loss of soil with slopes greater than 6 percent (Villar Sánchez 1996).

[17] An attempt is being made to examine the severity of fertility losses in different regions of Mexico as a function of soil class with data from INE and UNAM's Institute of Geography.

Table 4 Surface Affected by Different Degrees of Erosion

State	I	II	III	IV	V
Chihuahua	4,250,231	13,187,688	2,108,766	680,766	20,277,667
Sonora	2,507,527	10,869,618	3,254,781	166,168	16,798,094
Baja California	1,146,032	2,363,691	1,790,675	859,524	6,159,922
Baja California Sur	1,014,510	2,173,950	2,029,020	1,159,440	6,376,920
Durango	4,078,912	5,511,612	862,760	298,395	10,751,679
Zacatecas	2,056,712	367,270	3,085,068	1469,080	6,978,130
Sinaloa	1,169,760	1,111,272	1,228,248	1169,760	4,679,040
San Luis Potosí	1,666,464	2,810,533	575,241	31,947	50,084,185
Tamaulipas	796,020	2,388,060	1,353,234	1,194,030	5,731,344
Nuevo León	1,692,678	1,497,369	2,734,326	325,515	6,249,888
Coahuila	1,654,345	4,662,315	6,918,170	1,503,950	14,738,780
Jalisco	81,058	1,459,044	4,133,958	567,406	6,241,466
Nayarit	1,218,851	607,053	76,152	6,574	1,908,630
Colima	20,820	88,485	223,815	62,460	395,580
Aguascalientes	82,290	192,010	109,720	137,150	521,170
Michoacán	1,911,980	2,246,810	440,958	—	4,599,748
Guerrero	1,978,402	2,500,379	559,695	—	5,038,476
México	919,140	611,436	28,430	6,642	1,565,648
Guanajuato	505,825	873,749	382,783	217,894	1,980,251
Oaxaca[1]	1,413,165	2,724,220	1,844,220	2,026,330	8,007,935
Veracruz	3,461,667	96,339	1,806	945	3,560,657
Puebla	1,922,848	850,584	357,243	131,463	3,262,138
Tlaxcala	70,645	209,207	77,346	9,596	366,974
Morelos	293,193	109,724	13,487	—	476,404
Hidalgo	746,188	669,937	147,917	19,799	1,583,841
Chiapas	2124,444	447,407	64,284	—	2,636,135
Campeche	2,038,080	917,136	305,712	203,808	3,464,736
Quintana Roo	1,913,000	503,500	251,750	755,750	3,424,000
Tabasco	886,795	380,055	126,686	350,055	1,763,590
Yucatán	192,540	1,193,748	192,540	1,694,352	3,273,180
Distrito Federal	61,757	11,877	1,380	—	75,014
Querétaro	332,805	312,926	287,681	15,910	949,322
Total	44,208,684	63,949,004	35,567,852	15,064,709	203,920,364

Hectares. *Source: INEGI*, Estadísticas del medioambiente, México 1994, *Table II.A.4.8.*

Degrees of Soil Erosion: I Superficial erosion; II Moderate erosion; III Accelerated erosion; IV Total erosion; V Total erosion, by state.

[1] Oaxaca: The figure for column II is a residual of the others.

4. Biota

Corn cultivation in Mexico has an important impact on North American and global biodiversity. Much of the genetic evolution of corn varieties occurred in Mexico.[18] Mexico has become a center of genetic diversity for corn and Mexican germplasm has contributed decisively to the global production of corn.[19] Together with its wild relatives, the germplasm resources in Mexico's corn seeds and plants will continue to be of critical importance to the world's production of food.[20] Nowhere in the world is the spectrum of variation in maize as great as it is in Mexico, and nowhere is maize so deeply entwined with the cultural identity and social and economic life of the people (Wellhausen 1988, 21).

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[18] Studies of prehistoric Mexico have revealed the existence of primitive and small cobs in caves in Tehuacán in central Mexico that date to around BC 5,000 confirming that maize was first domesticated in South Central Mexico. (Wilkes and Goodman 1995; Hernández Xolocotzi, 1985; Wellhausen 1988.)

[19] Even the dented varieties of the US Corn Belt are close descendants of the first Mexican landraces (Ortega Paczka 1997).

[20] "…elite germplasm sources identified since the initial collections in the Americas have been incorporated into breeding composites, groups, gene pools, and populations by the CIMMYT Maize Program and national maize breeding programs worldwide. These in turn have been used to develop improved varieties and hybrids. In temperate regions Corn Belt germplasm predominates and in the tropics Mexican white dents and Caribbean yellow dents and flints have been successfully utilized in…maize breeding programs." (Taba 1995, 10).

Corn germplasm originating in Mexico has played a critical role in improving corn cultivated in tropical regions with respect to increased yield, plague resistance, short growth cycle, drought resistance and increasing protein content. Mexican varieties and their derivatives have been used to improve populations used in 43 tropical countries in Latin America, Africa and Asia (Taba 1995, Edmeades, Lafitte et al. 1994) and to increase yields in temperate regions at high latitudes (Ortega Paczka, 1997).

The genetic diversity of corn in Mexico is associated with the following dynamics:

- The interaction between genotypes and diverse agro-ecological environments. In most mountainous areas in Mexico, environmental heterogeneity results in a rich configuration of diverse productive spaces. Corn producers in Mexico have learned to take advantage of differences between agro-ecological systems.[21] In many agro-ecological systems in Mexico, producers will normally sow at least two varieties of corn, one for early maturity, which is less productive but more able to mature before the onslaught of freezing weather in mid-autumn, and one possessing a longer maturity period and a more productive life, but more prone to suffer the effects of this weather.[22] For many subsistence producers early maturity corn varieties are planted to supplement household consumption when the stock from their main harvest is exhausted (Ortega Paczka 1997).[23]
- Genetic diversity plays a role in producers' strategies as insurance against risk including drought, frost, winds, pests, and poor soil. The genetic diversity of Mexican maize responds to this multiple-faceted challenge through differences in maturity periods, drought and pest resistance, and efficient use of nutrients in poor quality, low nitrogen or acid soils. Mexican producers using traditional technologies for corn on rain-fed land rely heavily on genetic diversity as a strategy for survival. Different varieties of corn are sown by traditional producers at different times as a hedge against changes in rainfall patterns, climate, winds, soil quality and pests. Indeed, the adequate combination of seed variety and dates of sowing has been considered the most powerful technological resource available to traditional producers (García Barrios et al., 1991, 174–175). In addition, diversity in corn production in combination with other crops is important for production strategies such as intercropping.[24]
- Different end uses for corn require the maintenance and development of genetic diversity. These different uses help break dietary routines and play an important cultural role.[25]

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[21] Ecological systems are defined as topographical units of relative homogeneity in terms of soils, landforms, surface and groundwater, biota and topoclimates (Bailey 1996). Susceptibility to certain forms of land management and agricultural practices helps define an agro-ecological system. García Barrios et al. (1991, 134) coined the term agro-environment to describe the geographical space in which ambient factors which act as constraints for agricultural production are relatively homogeneous in the view of a producer.

[22] Two communities in southern Chiapas regularly employ at least eight varieties (Cadena Iñiguez 1995, 84).

[23] A study by Bellón and Taylor, quoted by Ortega Paczka (1997) identified six factors cited by farmers in a locality in Chiapas for seed selection: type of soil, drought resistance, wind resistance, response to inputs, critical period of vulnerability to weeds, optimum period of fertility and yields. No cultivar showed high values in five of these factors, so the majority of producers used on average three different cultivars. Other factors, according to Ortega Paczka (1977) include: uncertainty regarding the rainy season, different uses of maize (for sale, domestic and/or ritual uses), dietary considerations (grain texture and flavor) (Hernández Xolocotzi 1985). This could explain in part why corn varieties in Mexico vary in their productivity, ranging from low-yield primitive forms such as *Nal-Tel* and *Chapalote* to high-yield races such as *Tuxpeño*, *Chalqueño* and *Celaya* (Wellhausen 1988).

[24] A good example is documented by Cuevas Sánchez (1991) among the Totonacan peoples.

[25] Uses such as tortillas, *tlacoyos* (cooked corn pancakes with beans), *pozole* (corn grain in a broth), tamales, *atole* (a beverage made from maize dough), and *pozol* in Chiapas (a beverage made up of a blend between cocoa and maize grains) require different sizes, textures, colors, flour and starch contents. In many cases, traditional cultivars are favored because of their overall performance and contribution to final uses such as grain for human consumption, cobs for animals, or ear covers for tamales. Also important are certain maize varieties for the preparation of ritual beverages (*tezhuino* in the Huicot region and *atole* in the northern Puebla sierras), and the ramified ear corns used in fertility-related rituals in Chiapas (Ortega Paczka 1973).

- Patterns of property rights can be an important determinant of genetic diversity. If producers own plots with highly divergent traits such as quality, depth and drainage, they are forced to operate with a rich mixture of landraces[26] that respond to these different traits. This is typical of many producers in Mexico's *ejidos*.[27]

Traditional producers, numbering between 1.5 and 2 million, are a critical link in the maintenance and preservation of genetic diveristy. The 1994 *ejido* survey reveals that use of improved varieties and hybrids among corn-producing *ejidatarios* is low. This is true even in irrigated systems where the percentage of *ejidatarios* using improved varieties was 16 percent in 1994 while *ejidatarios* in rain-fed production used 8.8 percent (Gordillo et al. 1994, Table 5.7).[28]

Genetic erosion represents a loss of biota on a national and a global scale. Genetic erosion is traditionally defined as the loss of useful genotypes and alleles in landraces or local cultivars as they are replaced by modern improved (open-pollinated) varieties or hybrids, or as a result of the clearing of vegetation on a sufficiently large scale (National Research Council 1993).

Table 5 indicates that the abandonment of landraces in favor of hybrids and improved open-pollinated varieties (OPVs) has occurred throughout the world. The importance of landraces for production in developing countries is paramount. In 1992 a CIMMYT survey (CIMMYT 1994) indicated that open-pollinated populations accounted for about 42 percent of maize area in developing countries. In 1992 only about 21 percent of commercial seed sales in developing countries (except China) were open-pollinated varieties, attesting to the demand for hybrid seeds (Taba 1994, 15). There is evidence to suggest that landraces abandoned by traditional farmers often face extinction (Rissler and Mellon 1996, 115, and references therein), although germplasm banks may slow down or prevent this.

Table 5 World Corn Production: Cultivated Surface by Type of Seed, 1985–1992

1985	Maize Area (million ha)	MAIS (million ha)	Percent of Maize Area Under		
			Local materials	OPVs	Hybrids
All Developing Countries	81	37	55	7	38
Argentina, Brazil, China	32	24	28	1	71
Other Developing Countries	49	13	73	11	16
Industrialized Countries	57	56	2	0	98
World	138	93	33	4	63
1992					
All Developing Countries	84	49	42	15	43
Argentina, Brazil, China	37	30	18	9	73
Other Developing Countries	47	19	61	20	19
Industrialized Countries	48	48	1	0	99
World	133	97	27	10	63

MAIS: Maize area under improved seeds (commercially improved varieties and hybrids).
Totals may not add exactly due to rounding.

*Source:*1993/1994 World Maize Facts and Trends, *CIMMYT (Mexico 1994).*

Aquino (1996) estimates that landraces occupy 80 percent of the cultivated surface in Mexico. The 20 percent of surface cultivated with hybrids and improved varieties is consistent with the overall average figure (from the 1991

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[26] Landraces are collections of open-pollinated strains that come from farmers' fields or seeds collected in local markets.

[27] The main characteristics of the *ejido* regime were outlined in the Federal Constitution's Article 27, which served as the basic framework for land tenure. This article established that the *ejidos* would be the main category of land-holding for communities and centers of rural population. The *ejidos* were formed from the break-up of large, private, landed estates *(latifundios)* and *haciendas*, as well as from the colonization of unused land. *Ejidos* were made up of individual plots of land, as well as a piece of communal land. These parcels of land could not be sold, rented, or used as collateral.

[28] The same survey showed that 91 percent of producers who rely on landraces used their own seeds during the Spring-Summer cycle. For these producers, the conservation of genetic variability cycle after cycle is a matter of survival.

National Census) for all crops of 32 percent of total cultivated surface.[29] Taba (1994) reports that, "erosion of local landraces is occurring as they are replaced by improved open-pollinated varieties (OPVs) or hybrids. Original strains of local landraces, if not properly preserved either *in situ* or *ex situ*, or both, will be lost."[30]

Figure 2 illustrates the states with the highest rates of use of hybrids and improved varieties among corn producers in Mexico. It shows that local landraces are most frequently used in the southern and central highland states.

For private companies the production of hybrids is more profitable than OPVs for two reasons. First, heterosis effects make hybrids more productive than other seeds under similar conditions (water, soils and inputs). Second, yields go down at a faster rate after the first harvest and thus farmers must return to the firms supplying the hybrids for a new stock every season. Because improved seeds destined for the market are required to be of good quality and excellent presentation (color and size), continuously improved seeds are produced in Mexico by private companies under good production conditions (soils, irrigation or good rain fed regimes, inputs). Thus the seeds may not perform under tougher environmental conditions such as those in Mexico's highlands and semi-arid zones or in regions where soil quality is poor.[31]

Losses of genetic diversity and of information about landraces can also be caused by the substitution of corn by other crops or changes in agricultural techniques for a sufficiently lengthy period of time or a loss of cultural and social diversity (Ortega Paczka 1997).[32]

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[29] In Mexico as in many developing countries, landraces perform better than hybrids under stress and in poor or shallow soils (Lothrop 1994). Wellhausen (quoted in Ortega Paczka 1973, 31) noted that in poor soils improved seeds do not produce great differences in yields. In poor soil hybrids will frequently yield less than local landraces (Byerlee and López Pereira 1994). Other estimates for use of improved varieties by corn producers in Mexico are between 15 and 20 percent (Ortega Paczka 1997) and 25 percent (Ernesto Moreno, personal communication 1997).

[30] A recent FAO publication (FAO 1996) noted that genetic erosion in Mexico is well documented with baseline data provided by an inventory taken in the 1930s: "A comparison with current data shows that only 20 percent of the local varieties reported in 1930 are now known in Mexico due to decreases in the area of land planted with maize and the replacement of maize with other more profitable crops." This assertion is not well supported in the FAO study. It is possible that in certain localities which experienced the introduction of improved varieties in the 1950s and 1960s, or where crop substitution displaced corn for a sufficiently lengthy period of time, a reduction of genetic variability did take place, possibly in the order mentioned by the FAO study. However, this rate of depletion of genetic resources may not be valid at the national level and it is contrary to the opinion of most experts working on genetic resources in Mexico.

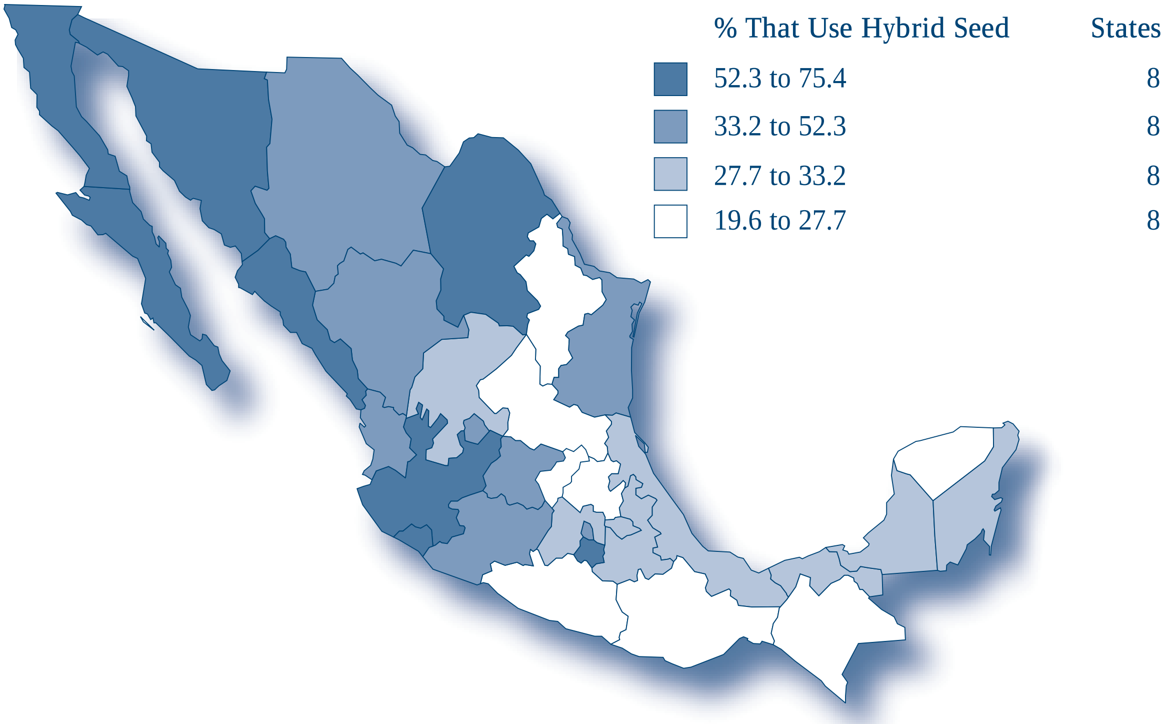
[31] Seed companies dominating the Mexican market are the following: Asgrow, Aspros, Cargill, DeKalb *(Semillas Híbridas)*, Pioneer and *Productora Nacional de Semillas* (Pronase). These companies offer technical assistance to producers, something that goes hand in hand with government efforts to privatize these services.

[32] This happened in El Bajío where maize was substituted by sorghum during the 1970s. This process also took place in the plains of Jalisco (due to sorghum), the lowlands of Morelos (horticulture and sorghum), the flatlands of Zacatecas (beans), Uruapan in Michoacán (avocado), and southern Yucatán (oranges). Large tracts of land in the tropical lowlands of Veracruz, Tabasco and Yucatán which were used for corn production under slash and burn conditions have been transformed to grassland.

In regions of Michoacán (the Tepalcatepec watershed), the displacement of landraces by hybrids started 25 years ago, and the fact that traditional cultivars remain in use is compelling proof of the extraordinary variety that existed before this process started (Romero and Ortega 1996,126). According to studies undertaken in 1992, in the state of Colima several important local landraces *(tampiqueño, ancho, uruapeño, perla and guino)* that were used with systems of animal traction have been displaced and some have disappeared. This process started in the early 1980s and by 1984 more than 31 percent of farmers were using certified improved varieties. A similar process took place in the highlands of the state of Guerrero, where high yield improved varieties descended from the Tuxpeño race have displaced landraces from the *Pepitilla* race (ibid, 1996).

In some regions, complete sets of varieties were abandoned as new fertilizer-responsive varieties were introduced. This was the case of the Bajío, where the *Conico Norteño* types that once prevailed there were wiped out in the 1940s and 1950s, and in Jalisco, where the *Tabloncillo* varieties were crowded out in the 1940s and 1950s as they were substituted by improved varieties (Wellhausen 1988, 23).

Figure 2 Maize Producer Units



Source: Calculations from VII Agricultural Census data, INEGI 1991.

Over time, genetic erosion can lead to the vulnerability and extinction of races and even species of maize. Once a genotype is lost, it is irretrievable.[33] The conservation of genetic diversity permits the use of primitive varieties of maize that can contain genes with attributes that allow the crop to withstand elements such as drought and plague. Mexico's germplasm complexes are rich in gene-based mechanisms for drought resistance and adaptation to changing environments.[34] Drought resistance is important because drought can occur at any stage in a plant's growth.[35] Genetic diversity can also affect the nutritional value of corn.[36]

Genetic erosion caused by the introduction of improved high yield varieties and hybrids has already taken place in several regions of Mexico.[37] But in areas dominated by traditional producers who operate on poor soils and in other

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[33] The dangers associated with the genetic vulnerability of maize were demonstrated in 1970 during an epidemic of the southern corn leaf blight that destroyed a significant proportion of the crop in the United States. In the developing world, corn genetic erosion is a hazard and has been recognized by the world's leading experts in this field (see Taba 1995).

[34] Two relevant indications in many developing countries are seedling drought resistance and drought resistance in the middle of the growth cycle (Wellhausen 1988, 22-23).

[35] A hybrid developed at CIMMYT (H220) is a three-way cross with two lines derived from a Celaya-Conico Norteño germplasm complex, and a third derived from a collection of the race Bolita which originated in a valley in Oaxaca with little rain and very erratic rainfall patterns. Under conditions of severe drought, this hybrid yields more grain than any improved variety in the Bajío region. The full advantage of this hybrid is expressed in its yields when rain is normal.

[36] There is evidence that the nutritional quality of corn products such as tortillas made with dough from industrialized corn flour is significantly inferior to those made from hominized maize (nixtamal) corn dough. (Personal communication, Dr. Juan Luis Peña Chapa, research fellow, Center for Research in Applied Science and Advanced Technology (CINVESTAV)).

[37] Among the reasons for the introduction of improved seeds, particularly of hybrids, the efficient response to inputs (especially fertilizers) and the adaptability to mechanized cultivation have been of critical importance, but not necessarily the improvement of grain quality in comparison with traditional landraces. Imported yellow corn from the US Corn Belt is considered to be of an inferior quality to grain produced by Mexican landraces or Mexican improved seeds, whether open-pollinated varieties or hybrids (Ortega Paczka 1977).

difficult environmental conditions (such as irregular rainfall and risks of early frost) genetic diversity has thus far been maintained. This *in situ* conservation of genetic resources is affected by changes in land use patterns and by the deterioration in resource management capabilities of households to produce corn for subsistence.[38]

Germplasm banks exist to preserve the gene pool intact by conserving samples of genotypes for use by plant breeders and the public at large.[39] This process is described as *ex situ* conservation to mark the fact that the genotypes in the samples have been removed from their original habitat. They have been the subject of some controversy with respect to their long-term viability (Cohen et al. 1991). *Ex situ* conservation in germplasm banks is not a panacea. The emergence of biotechnologies and transgenic crops as a result of genetic engineering will not create new genetic material. Moreover, it is very difficult to predict crop plant characteristics or features that must be sought in the future (National Research Council 1993, 43).

The first germplasm banks in Mexico began operations in the late 1940s.[40] There are now two principal seed banks in Mexico: CIMMYT and INIFAP.[41] At present, CIMMYT's collection of maize totals 13,200 accessions (individual samples of a distinct variety) (Taba 1995, 16). The germplasm bank in Mexico's INIFAP comprises approximately 10,000 accessions of native landraces that have been collected over the past fifty years. It also includes 1,539 native landraces from other countries and 144 *teosintes* [probable native ancestors of maize—see below].[42] Operations of the germplasm banks focus on seed identification, collection of new accessions or replacements, seed regeneration and characterization, supplying requests, and maintaining "passport" and seed storage information.[43]

However, seed banks lack information on the length of the plant's cycle—data of critical importance for planning seed replacement—because the sample's location has to be planned in accordance with its growth features. Replacing the seeds in an individual accession represents a critical moment in the life and operation of a seed bank. But seed replacement normally takes place in experimental stations that might have some, but not all, of the environmental conditions surrounding the original location where the seeds were collected.[44] These sometimes very different conditions can have a significant impact on replaced populations and the original characteristics cannot be expected to survive over time.[45]

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[38] The importance of maize genetic diversity in Mexico is also highlighted by the role germplasm from Mexican corn has played in global food production. Although germplasm from Mexican varieties is not present in important amounts in Corn Belt maize, the main varieties are descendants of Northern flints and Southern dents, which were derived from Mexican ancestors, showing special affinities with the cylindrical *Tuxpeño* of Mexico's eastern coastline (Wellhausen, Roberts, Hernández X. and Mangelsdorf 1951) and with other racial complexes found in Mexico (Hernández Xolocotzi and Alanís Flores 1970). In addition, Mexican corn germplasm is present in a very significant amount in varieties used in tropical countries around the world (Ortega Paczka 1997).

[39] The principal users of the germplasm banks are the large private seed companies.

[40] For a summary of CIMMYT's seed bank, see Wellhausen 1988.

[41] In addition to these two seed banks, there are several official banks operating in other countries, as well as private collections. The most important seed bank in the United States operates under the auspices of the US Department of Agriculture, National Plant Germplasm System. This bank has an active maize germplasm collection of more than 12,500 accessions, and is located in Ames, Iowa. Many of the accessions are duplicates of varieties in CIMMYT's and INIFAP's banks. But these varieties are kept under stricter and better physical conditions, such as under cryogenic storage conditions which make the need for replacement less urgent as seed viability is expanded considerably. The comparative conditions under which the different germplasm banks operate raises serious questions regarding future control and ownership of maize genetic resources.

[42] Many of these varieties have been carefully studied, but a surprisingly small number of accessions have been utilized in genetic-improvement programs: Ortega Paczka (1997) reports that no more than 100 have played an important role in these programs and only 40 (0.04 percent of the total INIFAP base collection) have supplied genetic material to improved OPVs and hybrids used widely in commercial production.

[43] The passport information includes data on collection and main features of every sample. Passport information is frequently scanty, with little or no references to the initial conditions of farmers who supplied the sample, or the exact location of the production site of the collected specimen.

[44] In Mexico, seed replacement and sample expansion has been taking place in a few experimental stations. In the case of INIFAP these stations are Chapingo (state of Mexico, just twenty kilometers east of Mexico City), Roque (state of Guanajuato) and Iguala (state of Guerrero). The extraordinary variety of soil characteristics, climate, precipitation patterns, pests and interaction with other plants and insects, cannot be replicated in these stations. CIMMYT'S stations (El Batán, state of Mexico, near Chapingo, Tlaltizapán, state of Morelos, and Poza Rica in the state of Veracruz) cannot reproduce the characteristics of the collection's original sites.

[45] Ortega Paczka (1997) notes that in the early 1980s he was shown maize seeds in Russia that were descendants of the Mexican samples. Because of crosses with Russian plants and other important factors, these samples did not resemble the original Mexican corn samples.

It is thus important to value the role of *in situ* germplasm conservation carried out by farmers and growers both for commercial purposes and household consumption.[46] Landrace diversity comes from age-long cultivation by farmers who use the genetic potential of their crops in their particular agro- and ecological environments. These varieties are constantly subject to selection, migration (mixing with other farmers' accessions) and mutation (Taba 1994, 22).

There are a number of advantages to *in situ* conservation (Dempsey 1996, 4–5).[47] First, continued evolution among crops and their relatives generates new variants and adapts them to future changes in pathogens, pests, climate, and even social conditions. Simply preserving the crop's germplasm without considering other elements of the genetic system in which it co-evolved could lead to a distortion of evolutionary patterns over time.

Second, *in situ* conservation maintains more seed varieties. The sizes of the population samples pose serious problems for seed replacement intended to maintain the viability of accessions. There is evidence of genetic shift and genetic drift as two of the most serious problems afflicting seed banks.[48] Scientists cannot track every global agroecosystem. Thus it makes sense to rely on the observation, selection, and general ecological knowledge of farmers (as well as the assistance of natural selection) whenever possible.

Third, frequently crops adapt to local conditions because of adaptive gene complexes that develop where genes become linked and selected interdependently. It is difficult to identify and isolate the particular resistance loci, alleles and genotypes that are useful in the stable control of disease.

Fourth, in many cases, *ex situ* conservation storage is only a supplement to *in situ* conservation, particularly where species are difficult to store or where multi-species associations exist and require ecosystem-level conservation. There are large regions with surviving areas intercropped, open-pollinated, landrace production, with opportunities for hybridization among cultivars and with their wild relatives. It is well known that changes in agronomic environments can result in an increased pathogen population without any changes in the genetics of the pathogen. Thus, a minor pest today may rapidly evolve into a major problem in the future.[49]

Finally, *in situ* conservation has the advantage of being compatible with schemes to introduce elements from improved varieties to landraces without reducing their characteristics or their variability. This process can improve desirable characteristics in landraces.[50]

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[46] It is important to distinguish *in situ* conservation from static conservation of germplasm. In a study focused on *in situ* conservation of the genus *Zea* in the Sierra de Manantlán, state of Jalisco, Benz (1988) helps dispel the confusion regarding a conservationist (static) view of *in situ* conservation. The old idea that native landraces remain static and do not suffer an (dynamic) evolutionary process is gradually receding and a more accurate view regarding dynamic conservation is gaining more supporters (Ortega Paczka 1997). More recently, a study by Louette and Smale (1996) reveals the dynamic nature of corn seed management in a rural community in Mexico.

[47] They are examined in a growing body of literature (National Research Council 1993; Nabhan 1989; Louette and Smale 1996; Crucible Group 1994; US Congress OTA 1986). Perhaps the most important advantage of *in situ* conservation is explained by Dempsey (Id.) as follows:

"… preserving seeds alone ignores many dimensions of agricultural diversity which have helped to sustain communities and have generated many of the resources we wish to preserve. For example, local knowledge of complex cropping patterns may allow more efficient use of niches created by local climate and soil variation. Informal systems of seed exchange are important for many farmers with uneven access to water, chemical inputs, credit and markets. Some of these social defense mechanisms may be lost or threatened by the introduction of new varieties. *In situ* conservation implies the maintenance of an appropriate social environment, if possible. However, economic and political changes can undermine traditional rural livelihoods. Neighborhood effects disperse pollen, seeds, chemicals, and price impacts across field and social boundaries."

[48] Genetic drift refers to changes in allelic frequencies in small populations. In very large populations the frequencies of neutral alleles remain stable between generations. But in populations which are reduced (as in the samples in a germplasm bank) random fluctuations in allelic frequencies will occur. Genetic shift is related to changes in allelic frequencies due to selection during regeneration of seed samples.

[49] A good example is the recent development of gray leafspot disease *(Cercospora zeae-maydis)* of maize into a disease of potential importance in the United States.

[50] Marquez Sánchez (1993) reports on the application of limited backcrossing techniques to carry out selective flows of useful genes to improve performance of landraces. A study quoted by Taba (1994) considers that as many as 250 Latin American maize landraces could benefit from this kind of program, but strong support is required.

Wild Relatives of Corn

Wild relatives are important gene repositories for domesticated crops. Maize probably derives from Mexican teosinte (Beadle 1977; McClintock 1977; Lothrop 1994). *Teosinte* can produce fertile hybrids with corn, and the two plants constantly exchange genetic material in many regions of Mexico and Guatemala (Wilkes 1977).[51] *Tripsacum* is a highly diverse genus that is adapted to a wide range of soil and climatic conditions and shows resistance to heat stress, drought, waterlogging and certain foliar diseases and insect pests. The importance of genetic diversity, not only of corn, but also of its wild relatives, is evident in the discovery in 1977 of a new species of wild perennial teosinte, *Zea diploperennis*. Recognized as a separate species in 1978, this plant is interfertile with annual corn and is the carrier of genes for resistance to seven of the nine major viruses that infect corn in the United States (Raven et al. 1992, 693). For five of these, no other source of resistance is known and the economic implications are immense. *Teosinte* populations are already declining at rates such that they could become endangered. A National Research Council study (NRC 1993) indicates that out of the eight distinct population clusters of annual teosinte, three are considered rare and occur at single locations. *Teosinte* and *Tripsacum* have not been widely utilized in maize breeding programs (Savidan et al. 1995; Berthaud et al. 1995; FAO 1996, 280).

Germplasm from Mexican corn exists in varieties throughout the developing world and is important for future food production as most of the growth in demand for maize will come from developing countries where demand has been projected to grow at four percent per annum but production has risen at a rate of only three percent. Much of this future growth will have to come from greater yields as opposed to the cultivation of additional land (CIMMYT 1994, 7; Plucknett and Smith 1982), and genetic resources from Mexico could play an important role in improving production in these countries.

B. The Economic Context

Activity in the Mexican economy has been characterized in recent years by patterns of structural adjustment that include trade liberalization efforts, monetary policy objectives focusing on reducing inflation and stabilizing exchange rates, fiscal policy designed to reduce public expenditures, privatization, and a reduction of a direct role for government in the economy. In Mexico several important macroeconomic objectives were achieved between 1990 and 1994; most notably, inflation was reduced and a fiscal surplus has been available since 1991. However, a reversal of capital flows in 1994 led to an exchange rate adjustment and in the wake of the crisis that followed and the ensuing stabilization program, inflation reached 52 percent, interest rates rose and GDP declined by more than six percent. Agricultural GDP had been stagnant since 1992. It dropped in the wake of the crisis in 1995 and by 1997 had not regained 1994 levels.

General trends in the Mexican economy have an impact on corn production. Historically, the share of corn production as a percentage of total agricultural production in Mexico has been around 50 percent. However between 1991 and 1994 there was an increase in corn production in irrigated systems, particularly in the rich irrigated lands of the northwestern state of Sinaloa. Between 1991 and 1993 corn production in Sinaloa increased by a factor of 2.4. Yields are generally very competitive in irrigated systems.

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[51] The work of evolutionary biologist John Doebley has recently confirmed that maize evolved rapidly from *teosinte* and that only a few genes were involved in this transition (Culotta 1991).

The growth in domestic production between 1991 and 1993 was significant at almost four million metric tons. Table 6 shows that this growth was due largely to the expansion of harvested area. Harvested area devoted to corn production increased by 3.3 percent between 1991 and 1993, and by 11.5 percent between 1993 and 1994.

Table 6 Structure of Agricultural Production in Mexico

	Maize	Wheat	Sorghum	Rice	Dry Beans	Soybeans
Relative Share of Total Cultivated Surface (%)						
Avg., 1981-85	59	8	13	1	15	3
Avg., 1986-90	57	9	15	1	15	3
Avg., 1991-93	63	8	11	1	15	3
1994	62	7	10	2	16	3
Relative Share of Production (%)						
Avg., 1981-85	52	17	22	2	4	3
Avg., 1986-90	62	18	23	2	4	3
Avg., 1991-93	50	14	23	2	4	3
1994	63	14	13	2	5	3

Source: Sagar, Boletín de información mensual del sector agrícola *1995; AIRD 1995.*

Corn production takes place in two well-defined cycles: spring-summer (S-S) and autumn-winter (A-W). The spring-summer cycle is dominated by rain-fed systems and may begin in March or April if water from irrigation systems or residual humidity is available. June is the most common month in which to start production under strict rain-fed conditions. The A-W cycle usually starts in November or December and is made up principally of irrigated systems. The A-W cycle is normally carried out using relatively modern technologies and techniques, including irrigation, improved varieties and hybrids, tractors, chemical fertilizers and pesticides. This is true for the private sector and *ejidos* (see Table 7).

In 1991, there were 3,151,399 corn-producing units in Mexico. The total number of production units operating in the Spring-Summer cycle was 2,679,813 (85 percent of the total). In 1991, more than 81 percent of total corn production came from land cultivated in the Spring-Summer cycle, where use of rain-fed systems prevails (see Table 8).

Table 7 Corn Production: Cultivated and Harvested Surface and Yields

	1991	1992	1993	1994	1995	1996
Cultivated Surface[1]						
Basic Grains[2]	11,032	10,915	11,361	12,698	12,476	N.A.
Corn	7,730	8,003	8,248	9,196	9,055	N.A.
Harvested Surface[1]						
Basic Grains[2]	10,005	9,521	10,239	11,334	11,018	10,341
Corn	6,947	7,219	7,428	8,194	7,963	7,516
Yield[3]						
Basic Grains[2]	1.82	1.98	2.05	1.90	1.88	N.A.
Corn	1.84	2.12	2.20	1.98	2.02	N.A.

[1] Thousands of hectares; [2] Rice, beans, corn, wheat.
[3] Metric tons / cultivated surface

Source: Sagar, Boletín de información mensual del sector agropecuario; *August 1996.*

Table 8 Corn Production by Agricultural Cycles

Spring–Summer				
Producers	Units	Surface (a)	Production (b)	Yields (b)/(a)
1–5 hectares	1,682,977	2,516,756	2,467,775	0.98
> 5 hectares	996,836	4,851,774	5,841,738	1.13
Total S–S	2,679,813	7,368,530	8,309,514	1.05 (avg.)
Autumn–Winter				
Producers	Units	Surface (a)	Production (b)	Yields (b)/(a)
1–5 hectares	224,822	289,917	309,428	1.07
> 5 hectares	246,764	943,411	1,609,319	1.71
Total A–W	471,586	1,233,329	1,918,748	1.39 (avg.)
Total S–S + A–W				
Total	3,151,399	8,601,859	10,228,262	–
1–5 hectares	1,907,799	2,806,673	2,777,203	–
> 5 hectares	1,243,600	5,795,185	7,451,057	–

Summary National Agricultural and Livestock Census, 1991.

Source: Author's calculations from National Agricultural and Livestock Census, 1991.

Yields for corn production have been low for the past two decades. They are dependent on a number of factors including geographic regions, technologies and techniques employed, plot size, and property right regimes. The average national yield, according to the 1991 Census, was 1.05 metric tons/ha for the S-S cycle (predominantly under rain-fed conditions) and 1.39 metric tons/ha for the A-W cycle (mainly irrigated systems). These aggregate figures mask important differences between corn producers, both in terms of sizes of plots, as well as in terms of the types of technology being used. Figures from the 1991 Census reveal an important difference in yields between the two cycles, with greater productivity in irrigated systems.

A preliminary look at differences in yields associated with different technologies appears in Tables 9–11, which show yields for rain-fed and irrigated systems for the Spring-Summer cycle in 1990 and 1994. Rain-fed systems that include improved varieties and fertilizer experience yields equivalent to, or better than, yields from irrigated systems. In 1994 the use of improved varieties and fertilizer in rain-fed conditions produced higher yields than the introduction of the same techniques in irrigated systems.

Table 9 Yields by Plot Sizes in *Ejido* Production of Corn

	Plot Size Yields (metric tons/ha)					
	< 2	2–5	5–10	10–18	> 18	All Plots
Rain-fed						
1990	1.14	1.14	1.22	0.97	0.93	1.11
1994	0.85	1.01	1.13	1.12	1.16	1.04
Irrigated						
1990	1.73	1.82	1.88	2.46	1.83	1.95
1994	1.59	1.81	1.17	1.15	1.86	1.49

Source: Gordillo et al. 1994 (Table 5.2).

Table 10 Yields in *Ejido* Corn Production by Agroecological Zones, 1994

Agroecological Zones	Average Yields (t/ha)	
	Rain-fed	Irrigation
Tropical Humid	1.05	1.47
Tropical Sub-Humid	1.17	1.77
Temperate Humid	1.22	–
Temperate Sub-Humid	1.19	1.82
Arid and Semi-Arid	0.62	1.68
National	1.09	1.69
	Spring–Summer	Autumn–Winter
Census 1991	1.05	1.39

Source: Gordillo et al. 1994; National Agricultural and Livestock Census 1991.

Table 11 Corn Production: Yields Under Different Technological Conditions

Spring–Summer Cycle (metric tons/ha)		
Rain-fed Systems	1990	1994
Landraces without fertilizer	0.85	0.85
Landraces with fertilizer	1.18	1.08
Improved Varieties w/ fertilizer	1.84	2.00
Irrigated Systems	1990	1994
Landraces without fertilizer	1.46	1.45
Landraces with fertilizer	2.06	1.59
Improved Varieties w/ fertilizer	2.26	1.45

Source: Gordillo et al. 1994 (Table 5.2).

Table 12 includes data on the profitability and competitiveness of producers based on the technologies and techniques that they use. The first panel classifies producers by their technology. A first group of 23 percent of all producers had average yields (2.8-3.2 t/ha) and therefore have the potential to improve their competitive positions. These producers are responsible for 50 percent of total production. They are probably net sellers in the market. For many of them productivity can be enhanced through technical assistance, infrastructure projects and adequate credit and other services that minimize market failure and distribute risk. The average size of their plots is high at 4.7 hectares for rain-fed land and 2.4 hectares for irrigated land. An intermediate group is made up of 50 percent of producers working on 48 percent of the land under rain-fed conditions and using either improved varieties or fertilizers. Their yields are low (1.5 t/ha). They work plots that average 2.5 hectares. The remaining 27 percent of producers work on 21 percent of the land and produce 10 percent of the total yield.

The second part of Table 12 includes data on the profitability associated with different categories of producers. The data indicates that one set of producers is profitable, while the other two operate at a loss.[52]

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[52] Both categories of producers are further subdivided into two subgroups based on the level of their profits (above or below 30 percent of costs) or their losses (above or below 50 percent of costs). This provides a rough indication of whether they sell in the market or not, and on how further price reductions may affect them.

Table 12 Profitability and Competitiveness of Corn Producers in Mexico, 1991

Distribution by Technology					
	I Rain-fed Landraces, no fertilizer	II Rain-fed Improved Varieties or Fertilizer	III Rain-fed Improved Varieties and Fertilizer	IV Irrigation	Total
Number of Producers	27.0	49.9	9.3	13.7	2,441,662
Surface	21.1	48.8	17.2	12.9	6,163,350
Production	9.5	40.9	26.5	23.0	11,174,408
Avg. size (ha)	2.0	2.5	4.7	2.4	2.5
Avg.yield (t/ha)	0.8	1.5	2.8	3.2	1.8
Production by unit	1.6	3.8	13.0	7.7	4.6

Distribution by Profitability					
	I Losses > 50% of costs	II Losses < 50% of costs	III Profits < 33% of costs	IV Profits > 33% of costs	Total
Number of Producers	27.8	36.4	16.4	19.4	2,441,662
Surface	24.0	32.1	15.7	28.3	6,163,350
Production	6.2	23.3	18.7	51.8	11,174,410
Avg. size (ha)	2.2	2.2	2.4	3.7	2.5
Avg.yield (t/ha)	0.5	1.3	2.2	3.3	1.8
Production by unit	1.0	2.9	5.2	2.2	4.6

Percentages and absolute numbers.

Source: Encuesta nacional sobre rentabilidad y productividad, maíz, *SARH 1991. (Reproduced in FIDA 1993).*

A second important difference is regarding the ownership rights involved: yields in private plots are 16 percent and 26 percent higher than yields for *ejidos* in rain-fed production and irrigated production respectively (Table 13).

Table 13 Corn: Yields by Ownership Rights and Plot Sizes

	Spring-Summer	Autumn-Winter
Mexico	1.13	1.56
< 5 ha	0.98	1.07
> 5 ha	1.20	1.71
Private	1.24	1.82
< 5 ha	1.01	1.09
> 5 ha	1.31	1.97
Ejido	1.07	1.44
< 5 ha	0.97	1.06
> 5 ha	1.13	1.58
Mixed	1.19	1.91
< 5 ha	0.97	1.09
> 5 ha	1.27	2.02

Metric tons/ha.

Source: Author's calculations based on Censo Agrícola y Pecuario 1991.

Data in Table 14 indicate that a final and critical difference in yields is related to the size of plots being cultivated. There appears to be a positive relationship between size and yields, independent of ownership rights or production cycle. The data suggests that this relationship is stronger with respect to irrigated plots in the Autumn–Winter cycle.

Table 14 Main Features of Production Units with Corn as Main Crop

		Spring–Summer Cycle		Autumn–Winter Cycle	
Attributes	Units	Units	Production (tons)	Units	Production (tons)
Total	3,151,399	2,679,813	8,309,514	471,586	1,918,748
< 5 ha	1,907,799	1,682,977	2,467,775	224,822	309,428
> 5 ha	1,243,600	996,836	5,841,738	246,764	1,609,319
Private	746,854	655,428	2,733,145	91,426	603,581
< 5 ha	486,125	433,172	512,486	52,953	59,712
> 5 ha	260,729	222,256	2,220,658	38,473	543,869
Ejidos	2,286,698	1,916,498	5,097,272	370,200	1,245,671
< 5 ha	1,359,022	1,190,897	1,854,469	168,125	244,740
> 5 ha	927,676	725,601	3,242,802	202,075	1,000,931
Mixed	117,847	107,887	479,096	9,960	69,494
< 5 ha	62,652	58,908	100,819	3,744	4,976
> 5 ha	55,195	48,979	378,277	6,216	64,518

Ejidos: See note 27 above.
Mixed: Publicly owned land rented to private entities for exploitation.

Source: Author's calculations from National Agricultural and Livestock Census 1991.

There are several possible explanations for these patterns, including the following:

- Privately-owned plots may have better access to credit and technology than *ejidos.*
- Private owners seem to invest more in infrastructure than *ejidatarios* perhaps because their property rights are better defined.[53]
- Larger units offer better opportunities for the introduction of more modern technologies (particularly mechanized traction) which are scale-dependent.
- In many instances the intrinsic fertility of soils may be higher in land that has been consolidated into a single plot.

Yield differentials are even more significant than revealed by this table. In the deep and well-drained soils of the Bajío region of central Mexico, yields can reach 7 or 8 metric tons per hectare. And in northern Jalisco, southern Nayarit, and Sinaloa, yields may exceed 13 metric tons per hectare. In all cases corn producers rely on modern technology and techniques, including high-yield varieties and hybrids, irrigation, mechanized traction and the entire array of agro-chemicals (fertilizers and pesticides). In these cases, plot sizes generally allow for economies of scale and producers are competitive.

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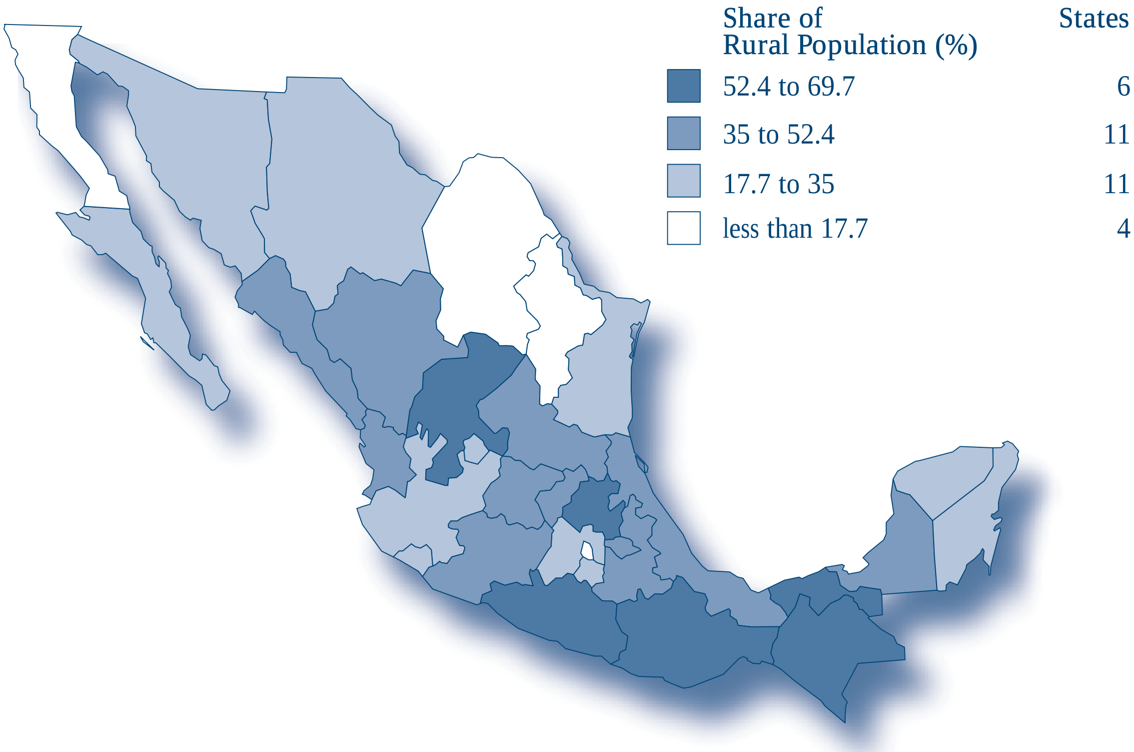
[53] This is one reason invoked by the 1992 reforms to the *ejido* regime. The literature on resource management under collective or social property schemes does not support the idea that there are intrinsic characteristics in this property regime that impair or forbid investments in infrastructure or in the long-term conservation of the productive assets of a community (Stevenson 1991). This literature does show that in order to prevent the "tragedy of the commons" syndrome, adequate systems are needed to control access to and use of the community's resources.

C. The Social Context

For the past 3,000 years corn production and consumption has been an essential component of the history and culture of Mexico.[54] Even today, Mexico's population is still largely rural, as indicated in Figure 3. In 1996 the production of corn directly engaged between 2.5 and 3 million Mexicans.

The role of religious and family bonds, in which reciprocity is a fundamental building block of social relations, has remained important in corn production. Many production techniques, particularly those that are labor intensive, depend upon these bonds. Dates of sowing and harvesting and agricultural cycles continue to be marked by cultural and religious festivities and are powerful drivers of collective work.

Figure 3 Share of Rural Population



Source: Calculations based on data from INEGI, XI Population Census.

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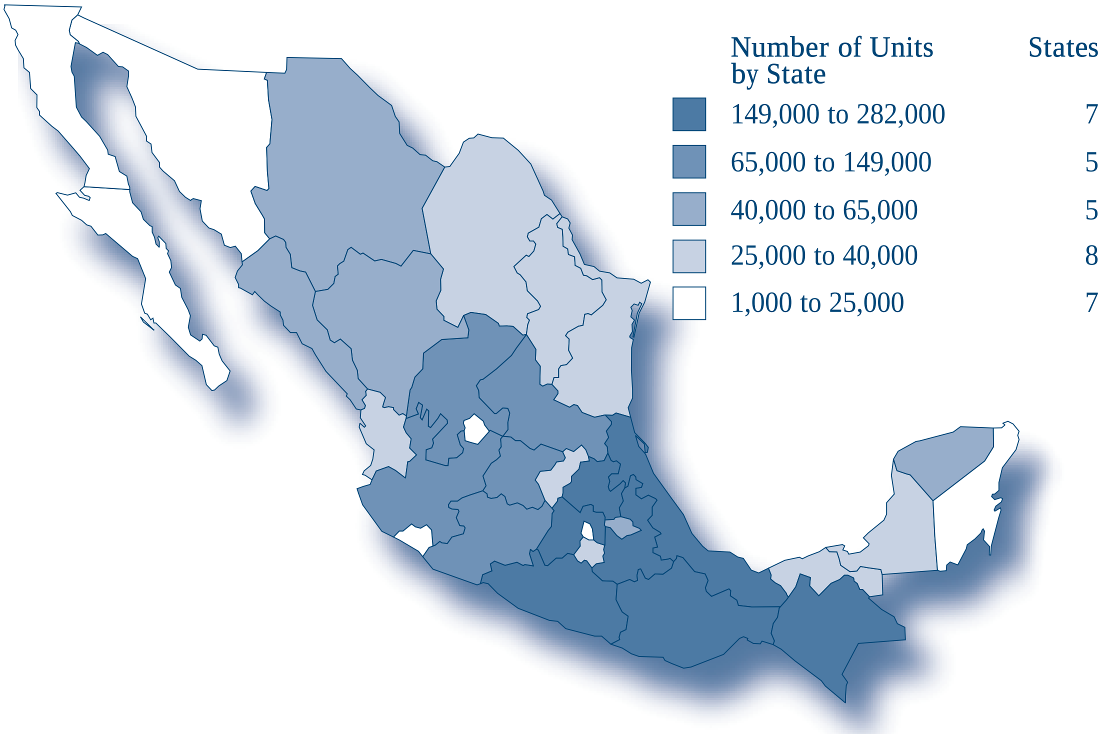
[54] Wellhausen, Roberts and Hernández Xolocotzi (1951) explain how dented corn already appears in a funerary urn of Zapotecan origin, as well as other pieces of pre-hispanic origin. These pieces and other evidence all confirm that corn played a very important role in the cosmogony of the people of Meso-America. The work of Chevalier and Buckles (1995) reveals how, even today, the mythology of rural communities weaves together a multitude of themes, ranging from procreation to consumption and production, through a complex pattern of relations in which corn production remains one of the main motifs.

Corn is produced by a variety of producer-types operating under different legal regimes. A dominant feature in corn production in Mexico is that the vast majority of land is fragmented into small holdings in the *ejidos*. Article 27 of the Federal Constitution has long served as the basic framework for land tenure in Mexico. It outlines the main characteristics of the *ejido* regime as the main category of land-holding for communities and centers of rural population. The *ejido* were formed from the break-up of large private landed estates *(latifundios)* and haciendas as well as from the colonization of unused land. *Ejidos* were made up of individual plots of land, as well as communal land. These parcels of land could not be sold, rented or used as collateral by their owners.[55]

More than 72 percent of corn-producing units are organized as *ejidos*. They are responsible for 62 percent of total corn production. Most of these *ejido* production units are small plots in which production takes place under very diverse conditions (from the point of view of technology and agro-ecological regions). According to the 1991 Census, almost 60 percent of production units operating under the *ejido* system were small plots of less than 5 hectares. Often these small producers operate in poor soils, with sloping terrain and under conditions of uncertainty regarding the regularity of the rain cycle, freezing temperatures, torrential rains and strong winds. Their technology profile normally excludes irrigation, mechanization and improved varieties or hybrids, although there may be a significant use of fertilizers and some pesticides. The techniques employed by the *ejidos* are generally relatively labor-intensive.

Figure 4 illustrates the number of maize production units by state in Mexico and Figure 5 illustrates the number of producer units of five hectares or less by state.

Figure 4 Maize Producer Units



Source: Calculations from VII Agricultural Census data, INEGI.

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[55] Under the *ejido* system land was subject to a social administrative regime of ownership in which individual families possessed plots but could not sell them or use them as collateral in credit operations. These plots were cultivated either individually or collectively (most land under the *ejido* regime is cultivated individually). The reforms of 1992 allow *ejidatarios* to sell, rent, or use their plots as collateral.

A comparison of two ejido studies conducted between 1990 and 1994 in Mexico reveals that although this basic structure remains, there has been a reduction in the number of smaller holdings. In 1990, units of less than five hectares accounted for 55 percent of the total number of units. According to the 1994 survey, units of less than five hectares represented 51 percent of all units. The number of units with more than 18 hectares has increased (Table 15).

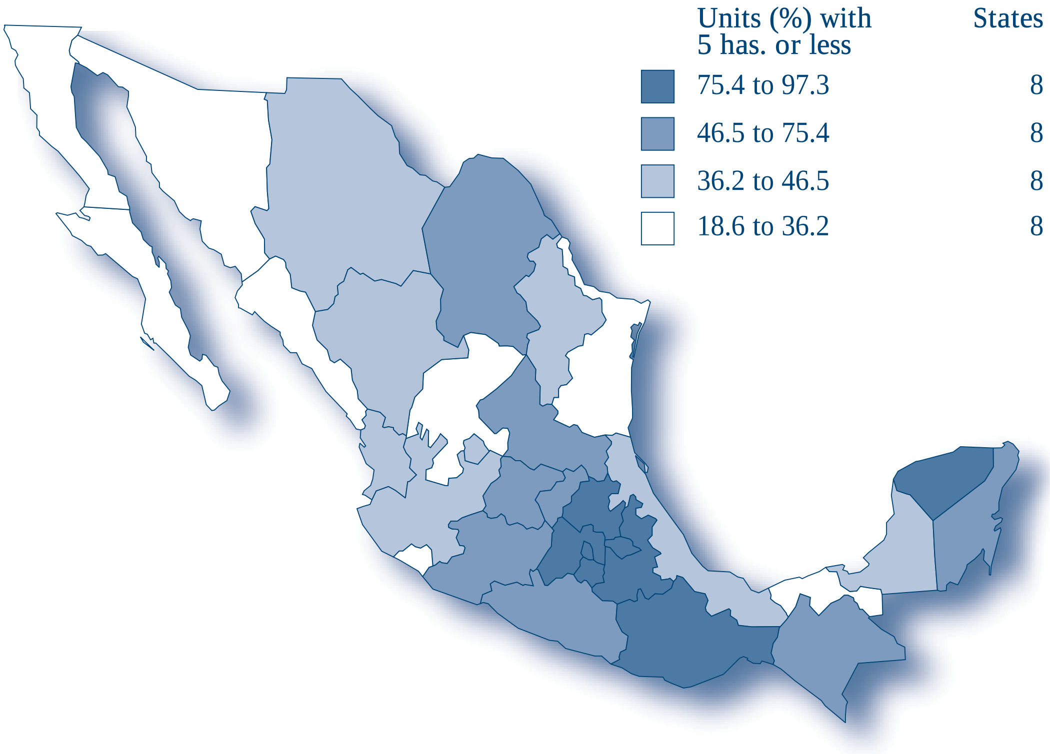
Table 15 Distribution of Plot Sizes in the Ejido Sector, 1990–1994

Survey 1990		Survey 1994	
< 2 ha ETN*	27.4%	< 2 ha ETN	19.4%
2–5 ha ETN	27.7%	2–5 ha ETN	31.6%
5–10 ha ETN	19.8%	5–10 ha ETN	23.1%
10–18 ha ETN	18.6%	10–18 ha ETN	16.2%
18 ha ETN	> 7.1%	> 18 ha ETN	9.7%

*ETN means these units are expressed in “national rainfed equivalent” units in order to allow for fallow and pasture lands owned by hese producers.

Source: El Sector Ejidal en la Agricultura Mexicana: Impacto de las Reformas. *Preliminary Report. (Ejido Survey 1994, Table 2.2)*

Figure 5 Maize Producer Units with Five Hectares or Less



Source: Calculations from the VII Agricultural Census.

The 1994 *ejido* survey also shows that yields dropped between 1990 and 1994. This has been attributed to unfavorable weather conditions. However, yields decreased both in systems under rain-fed and irrigated conditions. An additional factor might be the gradual deterioration of the technological capability of many categories of producers. Data produced by the *ejido* surveys of 1990 and 1994 confirm the positive relation between higher yields and increasing plot sizes. But this trend is not true of the largest plots (> 10 ha in rain-fed systems and > 18 ha in irrigated systems), where declining yields might be caused by inadequate technology.

According to the National Census, the number of agricultural producers who do not sell surpluses in the market is 1,757,611, representing roughly 46 percent of total agricultural producers. Although this is an aggregate figure for all types of producers of all crops, it probably corresponds very closely to corn growers producing for household consumption. The number of producers for whom corn is the main crop is reported in the Census as 2,752,020. Using these figures, one can approximate the percentage of corn producers who do not sell surpluses in the market to be around 64 percent. Thus, approximately 36 percent of corn producers sell their corn surplus in the market.[56]

There are no studies with information on the profitability of corn producers after 1994. The data in Table 12 remains relevant given the general structure of corn production in Mexico.

There are four major categories of producers useful for this analysis. These categories comprise:

- producers with highest profitability levels with the capacity to reconvert their operations towards the more profitable horticulture crops;
- producers with the potential to modernize corn production and compete with imports; and
- the third and fourth categories of producers who are engaged in production for household consumption, but with different resources and thus different production decisions.

D. The Geographic Context

Within Mexico, patterns of corn production vary widely by region. Corn itself is well adapted to a wide range of different climatic and soil conditions. It is cultivated in latitudes varying from the equator to more than 50 degrees and in altitudes between sea level and 4,000 meters above sea level. It is cultivated in fully-irrigated land as well as semi-arid conditions. The growing cycle may range from 3 to 12 months.

National production is thus distributed around the country (Table 16). But 51 percent of total production comes from five states: Jalisco, México, Sinaloa, Chiapas and Michoacán. Combined with Guerrero, Veracruz and Puebla, their contribution to total Mexican corn production is almost 70 percent (Figure 6).

Mexico's southern states of Guerrero, Oaxaca and Chiapas are responsible for almost 20 percent of total corn production. Those states tend to include a high proportion of producers working with little or no irrigation, and relying heavily on family labor. These producers tend to be poor and a significant part of their production is set aside for household consumption. Figure 6 illustrates the total number of corn-producing units by state and the level of production destined for self-consumption. The states of Chiapas, Oaxaca, Guerrero, Puebla, Hidalgo and Mexico concentrate many small production units that produce mainly for self-consumption.

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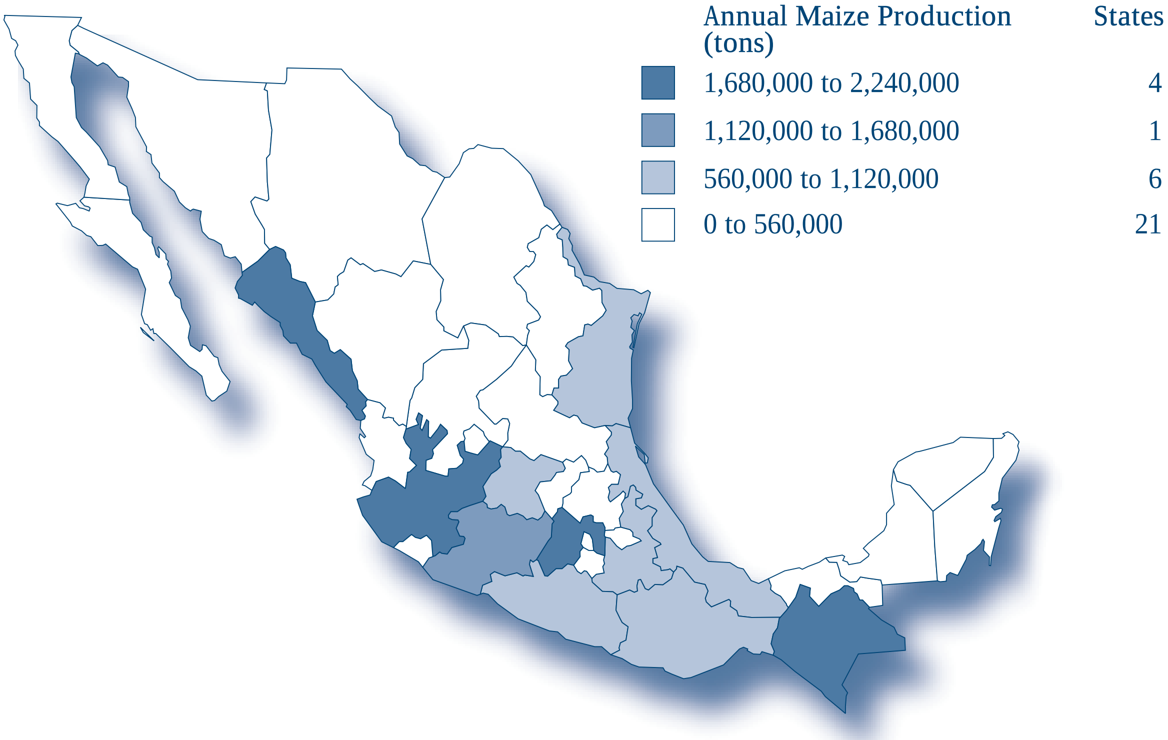
[56] There is some uncertainty surrounding these figures. The Agricultural Census (INEGI 1994) reported that the number of units producing exclusively for household consumption was 45 percent. Various sources put the number of corn growers who do not sell in the market at lower levels. Conasupo (1993) puts production for household consumption at 38 percent of total production. Appendini (1992) quotes another estimate for 1985 at 30 percent. The 1994 *ejido* survey concludes that 41 percent of *ejidatarios* included in the sample sell in the corn market part of their production (Gordillo et al. 1995). In their articles, de Janvry et al. (1995) and de Janvry (1996) comment that the *ejido* survey of 1994 revealed that 59 percent of corn producing *ejidatarios* are not sellers of any marketed surplus and produce exclusively for home consumption.

Figure 6 Maize Production by State

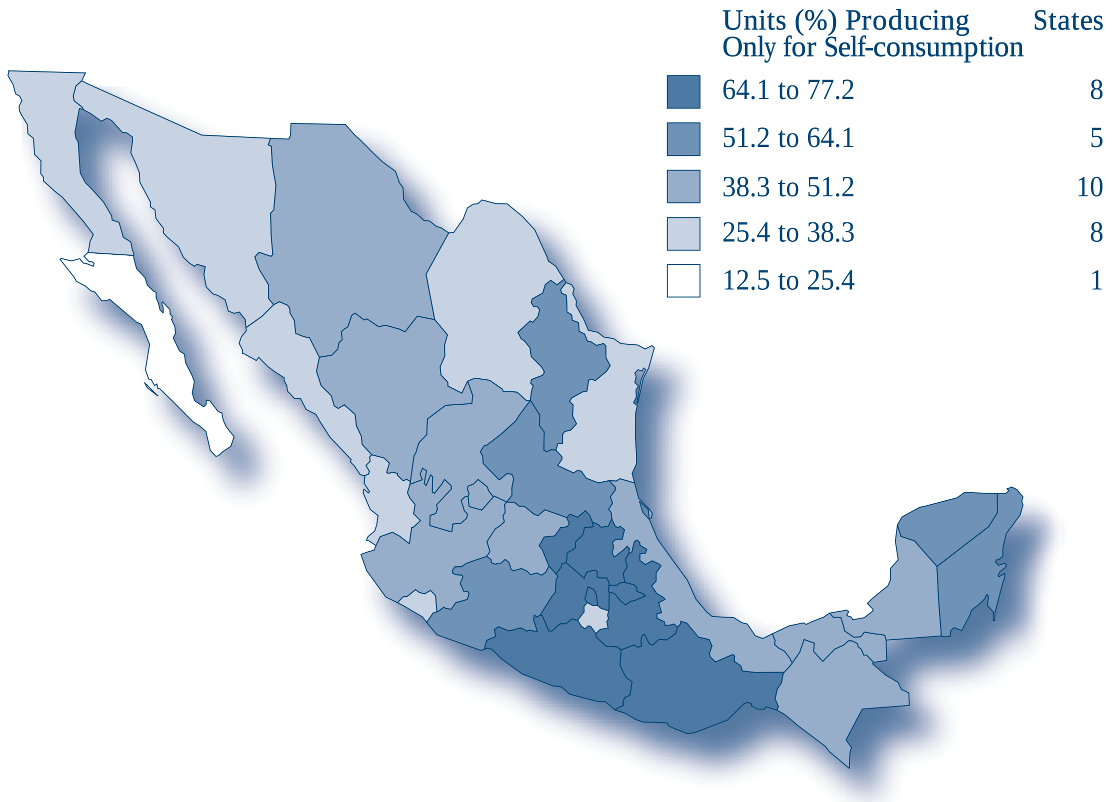


Source: Sagar.

A large number of production units are located in Mexican states where levels of rural poverty are high, often operating on sloping terrain and poor soil. In addition, rainy seasons are irregular and frost may appear in early spring or late summer, increasing risks for producers. These geographic features explain why producers rely heavily on a wide variety of landraces.

Table 17 presents Mexican states in order of importance according to the number of units relying on maize production as their main crop and employing improved varieties. This indicator can be used as a general reference for attempts to identify the profile of production units using local cultivars or landraces in their production. Two columns include data on the total number of units involved and the share of each state in total corn production.

Figure 7 Self-consumption Units



Source: Calculations from VII Agricultural Census data, INEGI.

Table 16 Corn Production at National and State Levels, 1985-1995

State	1985	1991	1992	1993	1994	1995
National	14,103,454	14,251,500	16,969,724	17,961,730	18,235,826	18,352,856
Jalisco	2,040,200	2,310,590	2,414,243	2,379,659	2,125,336	2,231,290
México	2,310,927	1,755,997	1,901,211	1,233,449	1,561,746	2,146,471
Sinaloa	222,854	821,000	1,080,913	2,442,387	2,762,275	2,027,474
Chiapas	1,460,524	983,415	1,607,369	1,593,298	1,096,254	1,696,001
Michoacán	875,444	979,195	919,481	1,039,760	1,042,268	1,293,058
Guerrero	814,860	786,516	989,801	886,835	765,736	1,112,254
Veracruz	757,809	797,570	852,557	761,335	929,953	1,104,281
Puebla	1,016,617	1,020,398	1,161,287	944,037	881,146	1,063,857
Guanajuato	505,636	532,760	777,912	1,255,706	1,020,245	824,005
Tamaulipas	755,793	443,304	746,921	1,108,759	1,355,550	818,609
Oaxaca	487,810	422,014	512,818	547,654	623,953	720,714
Sonora	189,506	393,714	295,566	455,175	542,981	457,480
Hidalgo	394,979	383,867	484,984	362,081	453,166	406,140
Chihuahua	357,368	739,955	948,238	880,086	487,031	303,627
Tlaxcala	337,624	262,051	376,081	263,250	310,065	297,076
Zacatecas	295,744	216,683	243,900	243,814	277,618	296,450
Durango	267,759	239,127	248,487	289,217	325,088	291,280
Nayarit	150,707	177,992	170,275	181,221	317,063	225,790
Querétaro	136,846	60,640	137,515	111,906	168,409	186,173
San Luis Potosí	163,358	210,361	149,713	88,618	193,209	160,989
Morelos	62,514	67,511	102,928	94,950	97,599	115,943
Tabasco	93,495	74,294	67,025	71,255	125,365	99,995
Colima	67,094	65,372	57,709	76,546	90,568	90,654
Aguascalientes	45,083	47,420	73,188	65,994	74,037	85,562
Yucatán	93,528	131,844	154,166	116,300	94,582	73,136
Campeche	48,015	55,565	111,163	82,135	115,314	54,889
Nuevo León	50,671	91,140	92,629	99,730	159,112	54,759
Coahuila	33,836	62,955	130,384	104,002	96,172	44,855
Baja California Sur	9,193	77,843	85,203	89,562	97,492	40,484
Distrito Federal	27,155	22,168	16,599	16,071	16,216	12,826
Quintana Roo	8,433	16,227	33,546	16,848	6,616	10,410
Baja California	22,072	2,012	2,5912	60,090	23,661	6,324

Metric tons.

Source: Sagar 1996.

Table 17 Maize Production Technologies by State

State	Units with Improved Varieties	Units with < 5 ha	Units with Tractors	Units with Irrigation	Units with Irrigation (Surface)	Share in Total # Units	Share in Total Production
Oaxaca	19.62	76.3	20.51	3.36	1.85	10.2	3.9
Yucatán	20.77	75.4	2.74	2.09	0.82	1.9	0.4
Hidalgo	20.98	83.5	36.78	18.35	11.50	5.4	2.2
Guerrero	22.35	74.0	13.76	2.81	1.92	6.1	6.1
San Luis Potosí	22.51	59.3	30.23	4.83	4.23	3.9	0.9
Querétaro	23.35	61.2	30.21	13.76	14.21	1.4	1.0
Nuevo León	25.38	46.1	36.17	12.05	12.48	1.0	0.3
Chiapas	25.40	50.7	17.89	0.68	0.44	9.2	9.2
Tlaxcala	27.72	85.5	61.69	9.41	4.44	2.1	1.6
Veracruz	28.47	44.3	27.95	0.83	0.87	9.0	6.0
Quintana Roo	28.76	59.1	8.92	0.63	0.30	0.9	0.1
Zacatecas	28.95	25.8	54.88	6.40	4.81	2.9	1.6
Puebla	30.97	83.0	32.82	7.62	5.68	9.7	5.8
Tabasco	32.64	33.5	38.67	0.28	0.35	1.2	0.5
México	32.74	91.5	41.53	16.20	10.41	9.0	11.7
Campeche	33.04	45.0	88.81	0.63	0.22	1.0	0.3
Distrito Federal	33.23	97.2	34.14	0.51	0.40	0.4	0.1
Michoacán	39.72	59.9	41.27	12.52	7.97	4.7	7.0
Durango	40.12	43.0	47.18	16.60	10.34	2.2	1.6
Guanajuato	43.10	46.5	47.60	14.31	14.28	4.0	4.5
Chihuahua	43.88	44.1	39.26	12.07	14.58	2.4	1.7
Tamaulipas	44.92	22.5	67.44	20.98	25.20	1.4	4.5
Aguascalientes	46.54	36.6	68.18	16.34	15.37	0.5	0.5
Nayarit	49.90	45.1	55.94	5.22	4.30	1.1	1.2
Colima	52.33	22.1	42.89	6.60	5.26	0.3	0.5
Jalisco	54.31	36.2	58.38	5.00	3.66	3.9	12.2
Coahuila	56.28	59.4	63.37	44.04	34.37	1.2	0.2
Morelos	57.17	78.0	60.32	14.63	9.97	0.9	0.6
Sinaloa	57.64	27.7	61.03	27.88	36.93	1.5	11.0
Sonora	67.63	33.4	74.86	46.71	63.41	0.5	2.5
Baja California	72.86	18.7	83.80	52.93	49.14	0.0	0.0
Baja California Sur	75.32	32.5	88.81	67.43	75.78	0.1	0.2
National Totals	31.40	54.5	34.77	8.61	8.97	100.0	100.0

Percentages.

Source: Author's calculation with data from VIIth Agricultural Census INEGI 1991.

In considering the figures in the first column of Table 17 one must take into account that the use of improved varieties and hybrids by corn growers is probably lower than in the case of other crops in most Mexican states.[57] In states such as Sinaloa, Sonora, Jalisco, Guanajuato, Colima and Nayarit, relying on more modern technologies and practices, corn production is carried out with improved varieties and hybrids. There are thirteen states in which use of improved varieties is below the national average[58] and which are responsible for 40 percent of total corn production in Mexico. Adding those states in which the use of improved varieties is less than 10 percent above the national average (Tabasco, México, Campeche, Distrito Federal), close to 52 percent of total corn production in Mexico originates from states where use of improved varieties is below 35 percent.

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[57] The two states in the Baja California peninsula are not representative of a trend as their contribution to total corn production is marginal.

[58] 31.4 percent.

In the thirteen states where corn production relies more heavily on local landraces, production is carried out predominantly under rain-fed conditions. Only in the cases of Hidalgo, Querétaro and Nuevo León is irrigation significantly higher than the national average. This coincides with the fact that corn production in these states is carried out in small production units (less than 5 hectares) with very little mechanization.[59]

Michoacán is a borderline state because the average number of units using improved varieties of corn is close to the national average. The same can be said for the incidence of small plots in the Spring-Summer cycle and for the use of tractors and irrigation. In addition, Michoacán's contribution to total corn production is substantial. Including this borderline state in the group of states where hybrid use is below or slightly above the national average, a geographic zone is created that is defined by a line starting roughly in the central Pacific states and crossing Mexico horizontally towards the east, including the state of Hidalgo (see Figure 2 above). Below this imaginary line there are roughly ten corn-producing states which contribute between 35 and 40 percent of national corn production, and where the use of landraces is most important.

Mean elevation in significant portions of these states is over 2,000 meters above sea level (masl), and sloping terrain predominates (with more than 70 percent of total cultivated surface located in slopes of four percent or more). Frost in the late summer or early autumn represents an important hazard for producers. The use of local landraces is explained by two main factors.

The first factor is that in most of these production units local landraces perform better than improved varieties and hybrids. This is due to the quality of soil, which does not allow the improved varieties to reach their full potential. The second factor is that producers use a wide variety of seeds as a means to counter the riskier production. Some improved varieties may be part of their strategy but in general, landraces are better suited in their adaptation to the minute changes in soil texture, humidity, rain patterns and disease.

These thirteen states comprise approximately 1,757,107 units of production. This is more than 65 percent of total units of production at the national level involved in corn production as their main crop in 1990. The maps on the total number of maize-producing units and on units smaller than five hectares corroborate this. Considering the mean size of rural families in Mexico is six persons per family, the total population depending directly on corn production in these states is approximately 10.5 million people.[60]

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[59] This information from the national census for corn producers *only* coincides with data from the 1994 *ejido* survey (Gordillo et al. 1995, Table 2.4).

[60] The information provided in SARH (1994, 50) confirms the importance of these states in terms of the number of producers.

III. The NAFTA Connection

A. NAFTA Rule Changes

Despite the large share and long-established centrality of maize production in Mexican life, NAFTA liberalization had a direct and substantial, if complex, impact on the sector. Chapter VII of NAFTA provided for an immediate conversion of the corn tariff system into a tariff-rate quota system to be phased out over fifteen years. An immediate tariff-free quota of 2.5 million metric tons of corn was granted by Mexico. The tariff-free quota is to expand at a compound rate of 3 percent *per annum* beginning in 1995. The transition period is considered very important by a number of commentators, in order to ensure the appropriate adjustment in the agricultural sector.[61]

The tariff for over-quota imports was set at 206.9 percent starting 1 January 1994 (approximately US$197 per metric ton). In NAFTA's first six years the over-quota tariff will be reduced by 29.6 percent of the base tariff. After this period, the remaining tariff will be phased out linearly over the subsequent nine years (Table 18).[62] By year 14 of NAFTA (2008) the tariff-free quota for corn imports will amount to 3.6 million metric tons, and in the fifteenth year all imports will have a zero tariff.[63]

NAFTA's impact on rules governing intellectual property is also relevant to a discussion of corn, although the impact is difficult to trace. Mexico's intellectual property system has existed since the late nineteenth century and Mexico has been an active member of the major multilateral intellectual property treaties covering patents, trademarks, and copyrights. This system has been modified through NAFTA.

Prior to the NAFTA negotiations, Mexico made important changes to its intellectual property law. Some of these changes were directed towards accommodating Mexico's patent system with trends underway in the Uruguay Round negotiations in the GATT on trade-related intellectual property issues (TRIPs, see GATT 1994) leading to an Agreement on Intellectual Property. In particular, extending patent life to 20 years, widening the coverage of patents, and defining more stringent controls for compulsory licensing were all critical items in the TRIPs negotiations.

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[61] Levy and van Wijnbergen (1992), for example, emphasize the importance of a sufficiently long transition period (they suggest 5 years) in which the pace of liberalization is accompanied by heavy investments in irrigation. Without this gradual pace of reform and adequate adjustment measures, their model concludes that all benefits accrue to the richer groups in both rural and urban areas.

[62] See Annex 302.2 in Schedule of Mexico, tariff item 1005.90.99.

[63] A similar regime was established for most basic grains.

Table 18 Basic Grains: Market Access into Mexico and NAFTA Quotas

	United States			Canada		
Year	Corn	Beans	Barley	Corn	Beans	Barley
1994	2,500,000	50,000	120,000	1,000	1,500	30,000
1995	2,575,000	51,500	123,600	1,060.9	1,545	30,900
1996	2,652,250	53,045	127,308	1,092.7	1,591.3	31,827
1997	2,731,817	54,636	131,127	1,125.5	1,639	32,781
1998	2,813,771	56,275	135,060	1,159.2	1,688.9	33,765.2
1999	2,898,184	57,963	139,111	1,229.8	1,738.9	34,778.2
2000	2,985,129	59,701	43,284	11,229.8	1,791.0	35,821.5
2001	3,074,682	61,492	147,582	1,266.7	1,844.8	36,896.2
2002	3,166,992	63,336	152,009	1,304.7	1,900.1	38,003.1
2003	3,261,929	65,236		1,343.9	1,957.7	
2004	3,359,786	67,193		1,343.9	2,015.8	
2005	3,460,579	69,208		1,384.2	2,076.3	
2006	3,564,396	71,284		1,425.7	2,138.6	
2007	3,671,327	73,422		1,468.5	2,202.7	
2008	—	—		—	—	

Quantities in metric tons. [64]

Source: NAFTA schedules 1994.

NAFTA's Chapter XVII on Intellectual Property brought about additional and important reforms to Mexico's intellectual property regime for plant varieties and plant breeders' rights.[65] Mexico joined the International Union for the Protection of Plant Varieties (UPOV) and enacted a new Federal Act for the Protection of Plant Varieties in 1996. In addition, Mexico introduced important reforms to its already existing Patent Law, introducing for the first time the possibility of patenting life forms. For the companies that are currently developing improved varieties and hybrids, and marketing their seeds (in the new deregulated setting), this new intellectual property regime is of critical importance. This policy instrument is important for the expansion of operations of these companies and for the protection of new hybrid and transgenic crops.

B. NAFTA's Institutions

Thus far, NAFTA's institutions, including those mandated to deal with agriculture, have done little to affect the dynamics of corn production in Mexico.

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[64] This study is limited in scope to NAFTA's corn regime, although in some instances references will be made to other basic grains and crops as they are relevant to corn. One example is provided by the case of kidney beans *(Phaseolus vulgaris)*, whose production is closely related to strategies of corn producers in Mexico. Beans are frequently sown in association with corn by many traditional producers. The dietary complementarities of the bean-corn couple perform a critical function in the daily livelihood of poor peasant families. In addition, the nitrogen fixation properties of the bacterium *Rhizobium*, which occurs naturally in the root nodules of bean plants, plays an important role in maintaining soil fertility. NAFTA immediately transformed the import license system for this crop into a tariff-rate quota, with the initial quota expanding at a compound rate of three percent *per annum*. Over-quota imports are subjected to an *ad valorem* tariff to be phased out over fifteen years, with a reduction of 30 percent by the end of the sixth year (bringing the initial tariff down from 133.4 percent to 93.9 percent). See Annex 302.2 in Schedule of Mexico, tariff item 0713.33.02.

[65] NAFTA Article 1709.

C. Trade Flows

The liberalization of the corn sector under NAFTA catalyzed a steady increase in corn imports into Mexico from the United States (Table 19). Indeed, since 1994, Mexican corn imports have exceeded levels in the tariff-free quota established by NAFTA. Total imports of 5.9 million metric tons in 1996 exceeded even the tariff-free quota for the 14th year of the transition period by 64 percent, even though during 1996 a record harvest of more than 18 million metric tons was recorded in Mexico (see Table 19).[66]

Table 19 Corn Imports by Mexico, 1985–1996

Year	Total Imports (metric tons)	By Conasupo (%)	By private importers (%)
1985	2,223,500	73	27
1986	1,703,500	71	29
1987	3,602,900	59	41
1988	3,302,600	70	30
1989	3,648,700	55	45
1990	4,102,800	46	54
1991	1,421,700	3	97
1992	1,313,700	2	98
1993	208,600	36	64
1994	1,717,000	0	100
1995	2,400,000	0	100
1996	5,900,000	28	72
1997 (1)	4,716,000		
1997 (2)	1,294,103		
1997 (3)	3,071,237		

(1) Imports approved for 1997.
(2) Effective imports during first semester.
(3) Probable total imports for 1997 estimated by ANEC

Source: Consejo Nacional Agropecuario, *Conasupo; ANEC.*

The years 1995 and 1996 were good for domestic corn production, yielding 18.3 and 18.2 million metric tons, respectively. However, extraordinary imports were authorized at a time when international prices were at their highest level in years.[67] It is expected that imports in 1997 will reach 3,071,237 metric tons. In the first nine months of 1997, imports totaled 1,864,659 metric tons, divided as follows: starch industries 1,185,267; flour industries 210,071; cereals 51,446; and feedstock 417,875 metric tons.[68]

In 1997, approved imports during the first semester totaled 1,720,398 metric tons. Effective imports during this period reached 1,274,090 metric tons. For July-September it was expected that authorized imports would reach 460,442 metric tons for a total between January and September of 2,180,840 metric tons. Total approved imports for the year 1997 will be 4,716,000 metric tons, but many analysts expect that effective imports will be less than this—between 3.5 and 4 million metric tons. However, by October 1997 reports about effects of the drought in several states

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[66] The imports were directed principally at livestock producers, milling industries and starch manufacturers. An important share of those imports was for the cattle feed industry. Animal consumption has risen steadily since 1990 and in 1993 26.7 percent of total consumption of corn in Mexico was as cattle feed, while 63.5 percent was for direct human consumption in various products, mostly as tortilla.

[67] The price of corn at Chicago's Mercantile Exchange rose from US$149 on 19 February to US$186 per ton on 6 May 1996. By 1 July 1996 the price of corn broke all records and reached US$212 per ton. In value terms, these imports amounted to approximately US$1 billion dollars.

[68] Data provided by ANEC.

had been released. In Tlaxcala, Chiapas, Guerrero, Puebla, Oaxaca and Hidalgo, more than 700,000 hectares were severely affected. Much of this land is devoted to corn. In a preliminary estimate, approximately 1.4 million metric tons of corn was lost (at 2 metric tons per hectare, average yields). This estimate is corroborated by data available in November 1997 suggesting that total production in the Spring-Summer cycle dropped to 13.5 million metric tons, a significant reduction from the same cycle in 1996 (14.7 million metric tons). It is possible that this will result in increased imports, certainly not less than the 3 to 3.5 million metric tons forecast.

It thus seems probably that imports of corn will continue to exceed the NAFTA's (transition period) tariff-free quotas, something confirmed by tariff-free import authorizations for 1997 and forecasts for 1998.

D. Transborder Investment Flows

Private investment in the corn-producing sector is negligible. On the other hand, foreign direct investment in processing industries has been active since the 1950s, particularly in commercial cereal production such as Kellogg's. No disaggregated figures are available about the recent evolution of foreign direct investment (FDI) in these branches of agro-industry.

E. Other Economic Conditioning Factors

The increase in corn imports beyond NAFTA-authorized levels indicates that several factors are affecting trade in this sector. One is macroeconomic policy. In addition to a fiscal surplus, monetary policy has maintained a slow growth of the main monetary aggregates, together with seasonal adjustment in the money supply. Interest rates and exchange rates have been tuned to the requirements of an open economy and deregulated financial and banking sectors. There has been a heavy reliance on foreign investment to finance Mexico's external deficit.

Since the Mexican peso crisis in December 1994, the government's adjustment and stabilization programs have provided a frame of reference conditioning production and trade in corn. The relative terms of trade of corn were initially affected by the devaluation of the peso between December 1994 and December 1995. In 1994 imports of US-grown corn became expensive relative to Mexican corn and for a brief time Mexican corn producers enjoyed a higher margin of protection. But this effect did not last, as the rate of inflation in Mexico in 1995 of 53 percent was considerably higher than rates in the Unites States of 4 percent.[69]

Thus, while some analyses stress the positive effects of the devaluation on the competitiveness of Mexican corn, any positive effects for corn producers brought about by the 1995 devaluation have virtually disappeared. The exchange rate is overvalued for the Mexican peso[70] and since the middle of 1996 overall imports have been growing faster than exports. The devaluation was part of an orthodox adjustment through relative prices and, as such, was accompanied by contraction in fiscal and monetary policies.

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[69] In 1996, inflation in Mexico was 26 percent. References to the devaluation and its impact on corn prices often ignore the fact that domestic inflation is not the same for all items. During the first quarter of 1995, average inflation was more than 16 percent. However, the price of fertilizers rose by 43 percent, agricultural machinery and equipment by 42 percent, and insecticides and herbicides by 38 percent. During that period, corn prices remained unchanged.

[70] By 10 to 15 percent according to the sources of comparison of inflation rates used.

Prices

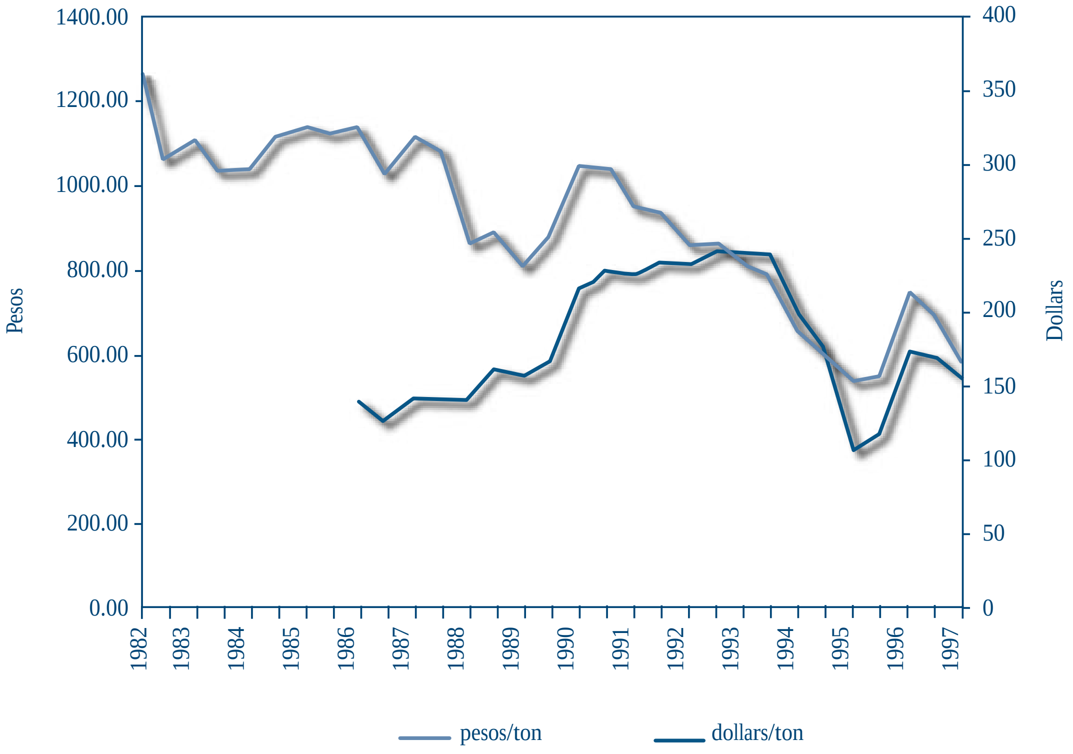
Since 1990 there has been a steady decrease in the real price of corn in Mexico (see Table 20 and Figure 8). Using 1994 as a baseline, guaranteed prices have dropped by 45 percent since 1990.[71]

Table 20 Real Prices for Corn, 1975–1995

	1975	1976	1977	1978	1979	1980	1981
	1232.9	1311.4	1260.4	1072.6	1089.0	1102.4	1267.7
	1982	1983	1984	1985	1986	1987	1988
S-S	1324.2	1117.6	1047.2	1137.3	1139.8	1118.5	857.1
A-W	1069.9	1038.8	1119.4	1126.5	1026.4	1082.5	885.7
	1989	1990	1991	1992	1993	1994	1995
S-S	809.5	1055.7	954.1	859.0	815.9	660.3	536.7
A-W	884.6	1045.6	938.1	860.8	789.0	590.8	552.6
	1996	1997					
S-S	755.3	571.4					
A-W	681.7						

All prices in 1994 pesos/metric ton. *Source:* Boletín de información mensual del sector agrícola, *Sagar. VI* Informe de Gobierno, *CSG 1994.*
S–S: Spring–Summer cycle. A–W: Autumn–Winter cycle.

Figure 8 Corn: Guaranteed Prices in Pesos and Dollars



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[71] Imports of corn increased sharply after 1994, and the downward trend for corn prices continued. The international price of corn resumed a downward trend in 1996-1997. After the reduction in world inventories during 1995–96 and the ensuing increase in international prices, corn production in the United States increased. Forecasts of demand from China, Japan and other large importers (including Mexico) give support to this renewed rationale for increased production. The new agricultural law in the United States supports expanded acreage for corn production. Today the price of corn is hitting US$2.4 dollars per bushel (US $110 per ton or $850-$900 pesos per ton). It is important to note however that there are indications that the international price of maize may rise in the next decade if there are no further increases in production (CIMMYT 1994).

Since 1996, the domestic price for white corn has been aligned with, or in some cases reduced below, international prices. Conasupo uses the international price for yellow corn as a guide for its support prices.[72] It then adds transportation costs to the point of entry and introduction costs to points of consumption in order to determine the "indifference price." Conasupo purchases corn at the "indifference price" thereby establishing a reference price for corn in the domestic market. The indifference price does not take into account the price differential between yellow and white corn in the international market.

The result is a price that incorporates all real costs and which lacks any degree of effective protection. The final and effective market price of corn is either equivalent to or below the indifference price. In many regions, producers encounter a buyers' market where the market price is below the international (indifference) price. The 15-year transition period established under NAFTA was designed to allow for the gradual alignment of domestic prices with international prices but this convergence has taken place in only two and a half years.

Table 21 shows that white corn is considered a distinct commodity and commands on average a price that is 25 percent higher than the price of yellow corn in the international market.

Table 21 Price Differentials Between White and Yellow Corn

	a	b	a/b
Year	White Maize	Yellow Maize	
1988	123	98	1.25510204
1989	134	103	1.30097087
1990	118	102	1.15686275
1991	115	98	1.17346939
1992	118.5	95	1.24736842
1993	97	93	1.04301075
1994	112	102	1.09803922

International prices expressed in US$/ton.

Source: Salinger, Metzel and Arndt 1995.

In Mexico, domestic prices continue to converge on international prices. Current corn prices in Mexico range from a low of NP$1,210 per ton in most states, to a high of NP$1,270 in Chiapas and NP$1,290 in Sinaloa. In Sinaloa a special bonus of NP$35 is available if certain quality standards are met, and another NP$20 bonus for dried maize. The indifference prices at the consumption zone are already in this range as can be seen from Table 22. The international price of corn has effectively become Conasupo's reference for its guarantee prices.

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[72] Conasupo is the agency responsible for food marketing and distribution and for the implementation of support policies for maize and beans.

Table 22 Indifference Corn Prices by Point of Entry and Consumption Zone

States	Port or Border	Consumption Zone
Baja California	1,094.18	1,163.95
Coahuila	1,008.32	1,137.39
Chiapas	969.22	1,124.82
Chihuahua	1,025.27	1,152.46
Distrito Federal (D.F.)	969.22	1,101.84
Guanajuato	1,008.32	1,206.35
Guerrero	1,022.22	1,218.26
Hidalgo	969.22	1,099.28
Jalisco	1,023.73	1,150.86
México	969.22	1,106.94
Michoacán	1,022.22	1,154.40
Nuevo León	1,008.32	1,124.62
Oaxaca	969.22	1,104.39
Puebla	969.22	1,086.51
San Luis Potosí	1,008.32	1,175.70
Sinaloa	1,023.73	1,143.20
Sonora	1,066.01	1,184.62
Tamaulipas	969.22	1,114.61
Veracruz	969.22	1,033.99

(26 June 1997) International Price (1994 pesos/metric ton).

Notes: Prices associated with maritime points of entry are averaged from prices of Yellow Corn # 2 in the Gulf local markets; others are averaged from data supplied by traders.

Source: Sagar, Center for Agricultural and Livestock Statistics (based on data from trading companies and brokers, FFCC, BUROCONSA and Banco de México).

Tables 23 and 24 present the relation between domestic guaranteed prices and the imported prices for corn and indicate the declining protection offered by the devaluation of 1994. The level of implicit protection (column 3, Table 23) increased to an average of 32 percent in 1995, when the peso was undervalued. By 1997, the difference between prices of imported grains and domestic guaranteed prices had virtually disappeared. In Monterrey the price of imports was lower than the guaranteed price.

Table 23 Domestic and Imported Corn Prices

	Support Prices /A	Prices of Imported Corn in Locality of Consumption /B (semester averages)			Implicit Protection /C (percentages)		
		Guadalajara	*D.F.*	*Monterrey*	*Guadalajara*	*D.F.*	*Monterrey*
1989(1)	370	342.19	327.53	322.64	-7.52	-11.48	-12.80
1989(2)	435	330.74	316.57	311.84	-24.05	-27.31	-28.39
1990(1)	600	388.88	372.21	366.66	-35.19	-37.96	-38.89
1990(2)	663	375.74	359.64	354.27	-43.33	-45.76	-46.57
1991(1)	680	394.10	377.21	371.58	-42.04	-44.53	-45.36
1991(2)	715	404.81	387.46	381.67	-43.38	-45.81	-46.62
1992(1)	715	429.15	410.76	404.63	-39.98	-42.55	-43.41
1992(2)	750	361.82	346.31	341.15	-51.76	-53.82	-54.51
1993(1)	750	364.50	348.88	343.68	-51.40	-53.48	-54.18
1993(2)	750	412.59	394.91	389.01	-44.99	-47.35	-48.13
1994(1)	650	486.02	465.19	458.24	-25.23	-28.43	-29.50
1994(2)	600	406.18	388.77	382.97	-32.30	-35.20	-36.17
1995(1)	658	822.12	786.89	775.14	25.04	19.68	17.89
1995(2)	815	1107.00	1059.56	1043.75	35.83	30.01	28.07
1996(1)	1300	1669.02	1601.52	1583.62	28.39	23.19	21.82
1996(2)	1300	1450.81	1406.03	1378.61	11.60	8.16	6.05
1997(1)	1200	1276.03	1208.89	1162.10	6.34	0.74	-3.16

A: Support and concerted prices practiced by Conasupo for A–W (1) and S–S (2) cycles.

B: From 1989(1) to 1995(2), the price in the locality of consumption was calculated by adding a fixed percentage to the international price which was 40 percent for Guadalajara, 34 percent for D.F. and 32 percent for Monterrey; for later years, data provided by ANEC was used.

C: (A-B)/A.

Source:Calculations from Conasupo, and Boletin de ANEC *(with data from USDA, CBOT, Sicsa and Acerca).*

Table 24 Guaranteed and Concerted Prices in Pesos and Dollars

Year	Constant[1]	Current	Exchange Rate	Guaranteed Prices (in US$)
1990 A–W	1055.75	600	2.77	216.2
1990 S–S	1045.60	663	2.90	228.4
1991 A–W	954.12	680	2.98	227.8
1991 S–S	938.07	715	3.05	234.1
1992 A–W	858.98	715	3.06	233.2
1992 S–S	860.83	750	3.10	241.3
1993 A–W	815.94	750	3.10	241.4
1993 S–S	789.00	750	3.11	240.6
1994 A–W	660.32	650	3.25	199.5
1994 S–S	590.76	600	3.51	170.6
1995 A–W	536.69	658	6.21	105.8
1995 S–S	552.59	815	6.77	120.3
1996 A–W	755.28	1300	7.49	173.5
1996 S–S	681.70	1300	7.68	169.1
1997 A–W	571.41	1200	7.87	152.4

Guaranteed price per ton.

[1] Constant 1994 prices.

Source: Author's calculations with data from VI Informe, CSG 1994; Sagar; Banco de México.

IV. Linkages to the Environment

The way increased imports and falling prices for corn impact the environment depends on the dynamics of production, physical infrastructure, social organization and government policy. The importance and independent impact of these processes is signaled by the economic anomaly that in the face of rising imports and falling prices, Mexican domestic corn production has been maintained or increased. This section begins with government policies that accompanied NAFTA. The second section focuses on production and technology responses associated with the changing macroeconomic regime that NAFTA is a part of. The third section considers the development of physical infrastructure. And the fourth section looks at the role of social organization in response to the macroeconomic regime that NAFTA contributes to.

A. Government Policy

The liberalization of trade in maize, with its rising imports and falling prices, promised a major environmental gain by reducing *de facto* subsidies for production on marginal lands and the environmental stress such production causes, and by intensifying patterns of specialization (Tellez 1992; Levy and van Wijnbergen 1992). The alignment of the price of Mexican corn with the international price of corn represents the end of these subsidies.[73] It is expected that the alignment of Mexico's corn prices with international prices will bring about significant domestic price reductions. Trade liberalization is accompanied by a new subsidies regime for agriculture in which price support systems are replaced by direct payments to producers. This is consistent with international trends and with the Agreement on Agriculture covering direct payments to producers and decoupled income support (GATT 1994, Annex 2).

Producers' incomes and their ability to maintain ecological supports were to be enhanced by several government programs: Procampo payments based on acreage owned rather than specific crops produced; FIRA credits to purchase seeds, fertilizers or pesticides; and Conasupo's purchase price for maize and beans.

The Conasupo system of support prices is subject to severe pressures. The same is true for payments under Procampo. Corn prices have dropped in real terms and Conasupo's overall operations have been reduced. Conasupo readjusted its prices in 1995-1996, but continued to lag behind market prices for 1995 and 1996. Procampo payments were 440 pesos per hectare in the Spring-Summer cycle of 1995: this means this item experienced a 25 percent nominal increase in 1995. In general, the real value of the direct income support has not kept pace with the declining price of maize for producers, lowering their overall ability to protect the environment. Moreover, the implementation of these programs may favor producers who purchase high technology input packages, states that produce corn on a competitive basis, and capital intensive industrial users of maize.

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[73] The relevant international price of corn for Mexico's producers is dominated by the price of corn in the United States. Cost and yield differentials between corn production in Mexico and the United States are significant: average corn yields per hectare in Mexico and the United States are approximately 1.7 and 7.0 respectively.

At the same time, the availability of credit through official development banks focusing on agriculture has been reduced. In 1994–1995 there was a sharp increase in non-performing loans which led the government to implement a financial rescue program for the banking sector. The rescue program has cost US $20 billion, but the non-performing index continues to grow (Nadal 1997). This could have social implications in rural areas.

This section reviews some critical government policies that affect the corn sector. Some were implemented in advance of NAFTA, some in conjunction with NAFTA. Those that are not related to NAFTA are described to establish the policy context in which the sector operates under trade liberalization.

1. Procampo

In recent years, support policies for corn have been maintained and transformed into a direct subsidy per hectare on the basis of land possession or ownership through a system of guaranteed prices for corn and kidney beans provided by Procampo, which started in 1994. Procampo provides direct payments to producers to compensate for income losses during the transition period as domestic prices converge towards international prices. This subsidy is consistent with trends in international trade negotiations regarding support policies in agriculture. It is considered to be a neutral force on producers' decisions regarding allocation of resources. Thus, it de-links support subsidies from specific crops, allowing producers to respond to market signals. Procampo applies to nine crops. In mid-1997 Procampo payments were set at NP$556 per hectare. They were to remain at a constant level for the first five years of implementation and would then be phased out over a ten-year period. The evolution of Procampo payments is set out in Table 25.

Procampo is designed to promote sustainable agriculture and the rational use of natural resources. Some argue that the crops which, in the past, enjoyed relatively high support prices were cultivated for the most part in regions with fragile soils, a pattern that encouraged erosion and the excessive use of fertilizers. The reduction of price distortions should thus result in a more efficient use and conservation of natural resources (OECD 1997b, 75). Procampo is also designed to deter environmental degradation by improving the living standards of producers and reducing the uncertainty of income flows. It is designed to prevent producers from cultivating slopes where the risk of erosion is high and to promote reforestation by continuing support for producers who devote land to forestry. In addition, it is intended to stimulate environmentally sound production and crop diversification by eliminating price distortions (SARH 1994).

The deregulation of the system of prices of key inputs such as fertilizers and pesticides or improved varieties and hybrids is another important element in the adjustment strategy, although it is not directly related to Procampo. This policy implies the gradual elimination of the price support system, placing producers in more realistic position vis-à-vis inputs, while at the same time increasing productivity. This should result in the more efficient use of fertilizers, herbicides and pesticides, leading to a reduction in the accumulation of residues in surface water bodies, diminishing depletion rates of water, and decreased pollution of aquifers.

Table 25 Procampo Payments in Real Terms, 1994–1997

Spring–Summer				
Year	Nominal (NP$)	Constant[1] (NP$)	Constant[2] (NP$)	Nominal[3] (US $)
1994	350	350	350	–
1995	440	440	440	–
1996	484	632	640	–
1997	557	778	800	69.6
Autumn-Winter				
Year	Nominal (NP$)	Constant[1] (NP$)	Constant[2] (NP$)	Nominal[3] (US $)
1993-94	330	–	–	–
1994-95	400	–	–	–
1995-96	440	440	–	–
1996-97	484	711	716	–
1997-98	557	832	852	69.6

[1] Estimated level of Procampo payments required to remain at constant values using the general consumer price index of the Mexican economy..
[2] Estimated level of Procampo payments required to remain at constant values using the price index for agricultural producers (input price index).
[3] Nominal Procampo payments at the following exchange rate, 1997: NP$8.00 per dollar.

Source: Author's calculations with data from Aserca 1997 <www.infoaserca.gob.mx> and using the price index of Banco de México.

Thus, some would argue that as tariffs are gradually phased out, subsidies progressively eliminated, support policies decoupled from production decisions, and price distortions abolished through deregulation, producers of white corn should cease cutting down temperate or tropical forests. Marginal lands should also cease to be exploited, putting an end to this source of stress on poor soils. Although environmental problems which pre-dated the NAFTA regime may persist, on balance the environmental impact of NAFTA's corn regime is positive. The new technologies which may be adopted and implemented with greater ease due to the new NAFTA regime would enhance this beneficial outcome for the environment.

There are some indications, however, that in many regions Procampo payments have been linked to purchases of fertilizers, seeds and/or pesticides.[74] In this manner, Procampo payments have started to play the role of very short-term credit lines for agricultural producers. This development is important given that inflation has affected agricultural producers disproportionately compared to the general price index. Table 26 illustrates the trend in prices of agricultural inputs between 1994 and 1996.

At the same time, rural credit institutions have virtually disappeared. One remaining institution is the *Fideicomisos para el desarrollo rural* (FIRA). But its operations essentially benefit privately-owned companies that produce and supply seeds, fertilizers and pesticides. This is done through a mechanism which involves Procampo and allows farmers to authorize the direct payment of Procampo checks to suppliers of seeds, fertilizers or pesticides. This operation receives supplementary support from FIRA via credit support to these suppliers of a chemical-intensive technological package. Additional emphasis on this technological package is provided in the *kilo por kilo* policy.

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[74] Personal communication, Pedro Aquino and Víctor Suarez 1997.

Table 26 Evolution of Prices of Agricultural Inputs in Mexico, 1994–1996

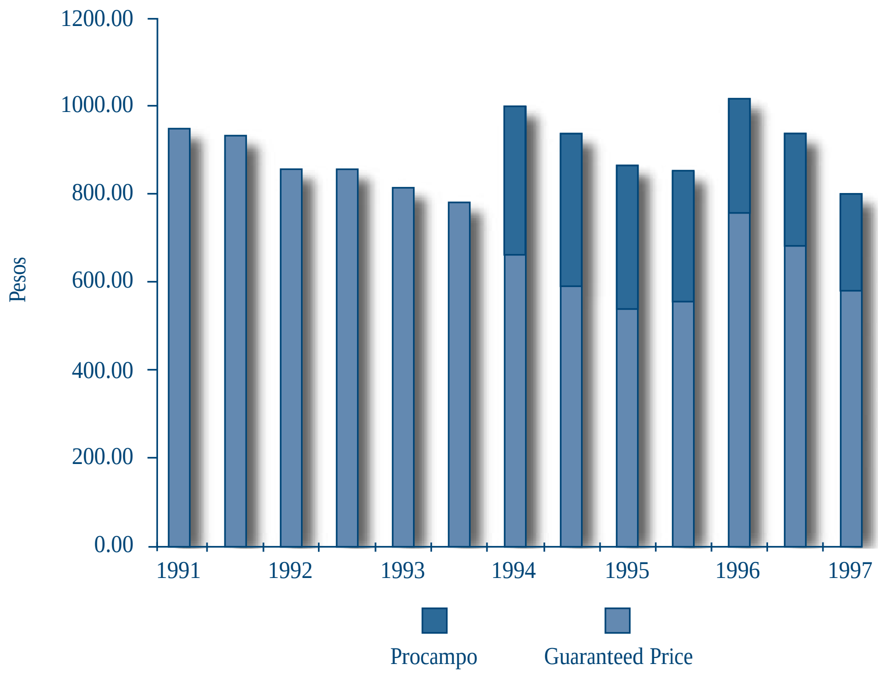
	1994	1995	1996
Farm machinery and fuel	100	162.49	197.23
Agrochemicals	100	152.9	215.8
Additives and fertilizers	100	148.3	218.3
Ammonium sulfate	100	152.1	219.5
Urea	100	160.3	264.6
Calcium superphosphate	100	136.7	182.5
Ammonium nitrate	100	137.9	197.5
Insecticides and pesticides	100	166.3	212.6

Percentage relationships based on 1994 NP$.

Source: Aserca and Banco de México.

Thus, it appears that the role of Procampo is changing. Initially designed as a compensatory payment delinked from production decisions, Procampo is gradually becoming an instrument that affects the choice of a technology that is not necessarily the best from the environmental perspective. Figure 9 indicates that the drop in real terms in domestic corn prices is resulting in lost income that is not being fully compensated by Procampo payments.[75]

Figure 9 Guaranteed Prices and Procampo Payments



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[75] The drop in corn producers' incomes stopped in 1996 as a result of an increase in corn prices due in part to rising international prices and in part to the evolution of relative prices in the Mexican economy, where adjustment for inflation in 1996 had to take into account high rates of inflation in both 1995 and 1996 (at 52 and 25 percent, respectively). Incomes dropped again after 1996 and Procampo payments did not maintain their value in real terms.

2. Conasupo

The C*ompañía Nacional de Subsistencias Populares* (Conasupo) is the state firm responsible for food marketing and distribution. It was set up in the 1940s. It is also responsible for the implementation of support policies for maize and beans, the two crops for which purchase prices are guaranteed. Conasupo's average purchasing price is higher than its selling price. The total subsidy is not equivalent to the price differential (between support prices and selling prices), but also incorporates the cost of transportation and storage.

In response to terms set out in Chapter VII of NAFTA, Conasupo's role in the purchase of domestic corn has decreased since 1994 when it began buying less corn from Mexican producers. This trend has continued into 1997. In addition, Conasupo is selective in its purchases of corn. It does not operate in all markets and tends to buy more corn in the highly competitive states of Jalisco, Sinaloa and, to a lesser extent, in competitive regions of Chiapas. It operates less in the states most vulnerable to competition where producers often have few or no alternatives given variables such as soil quality, altitude or latitude.

During the transition period Conasupo has been in the process of reducing its operations in volume, value and geographical coverage. Indeed, it recently bought 1.7 million metric tons of corn in 1996 at a price of US$1,335 per ton in Sinaloa, where producers operate in irrigated systems on good land with modern infrastructure (the same producers who could be producing more profitable crops).[76] At the same time, Conasupo has virtually ceased operations in other states such as Oaxaca, Guerrero and Puebla. The large inventories which Conasupo collected from its operations in Sinaloa are being sold at a lower price—some to foreign firms operating in the international commodity markets.

As Conasupo continues to reduce operations in value and volume terms, regional prices are impacted differentially because of strong differences in the extent of this institution's interventions. In some cases, domestic prices are even lower than international prices.[77] As of 5 November 1997, Conasupo had not announced its prices for the upcoming season, causing hoarding and speculative behavior on the part of market participants in many areas.[78]

While subsidies to producers are declining, those to consumers remain strong. "Consumption subsidies" are channeled through Conasupo's rates at subsidized prices to the big companies and millers of the flour industry (most of which are vertically integrated with tortilla production). Humans consume the largest proportion of corn in Mexico. However, corn for animal feed has risen steadily since 1990. In 1993 it accounted for over 26 percent of total consumption (Table 27).

Corn for direct human consumption is channeled through three different avenues. The first is the preparation of various food products (tortillas, tamales and other items) by subsistence producers. The second is through the preparation of hominized grain through a traditional process *(nixtamal)* which involves, among other things, the addition of limestone to the mix. The outcome of this process is corn dough *(masa)* which is then baked into tortillas. This process is used by thousands of small *tortillerias* across the country. These *tortillerias* are supplied by *nixtamaleros* (frequently chains of several dozen *nixtamal* units are owned by one person). The third is through the industrial manufacture of corn flour that is marketed as flour or, in the case of vertically integrated groups, processed into dough and tortillas that are sold as a final product.

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[76] At an exchange rate of $7.5 pesos per US dollar.

[77] Personal communication, Víctor Suarez, ANEC 1997.

[78] This is in the context of slight increases in international prices, uncertainty about El Niño, international demand from China, hurricanes in southern Mexico, and drought in some other corn-producing regions of Mexico. Personal communication, Victor Suarez, ANEC 1997.

Of the total supply of the basic input for tortillas, 50 percent is marketed to industrial producers of tortillas and 50 percent to n*ixtamaleros*. In the process of competition between these two technologies, the weight is shifting in favor of the capital-intensive industrial process. Preliminary indications show the capital-intensive industrial process possesses economies of scale and generates less employment than the smaller units operating with the *nixtamal* process. There are indications that this process of technical substitution is being promoted.[79]

Table 27 Corn Consumption by Destination

Year	Direct Human Consumption	Feedstock	Industrial Uses	Seed	Losses
1987	80.1	11.1	5.0	1.2	2.7
1988	83.1	8.2	4.9	1.2	2.7
1989	82.9	8.2	5.5	1.1	2.3
1990	79.4	10.6	6.6	1.0	2.4
1991	76.8	13.1	6.2	1.0	2.9
1992	74.4	15.1	6.4	1.0	3.1
1993	63.5	26.7	5.6	0.9	3.2

Percentages.

Source: Sagar, Centro de estadísticas agropecuarias, *1995.*

In the segment operating with industrialized flour, two large firms, MASECA and MINSA, control almost the entire market.[80] In 1996 the volume of operations with industrial corn flour was distributed among the major firms in the following proportions: MASECA 70 percent, MINSA 27 percent, Agroinsa 2 percent, Hamasa 1 percent. It is clear that the dramatic growth in the volume of sales of industrial flour, even in the midst of the economic crisis, is due to the rapid conversion of this market to the use of industrialized flour in the production of tortillas. MASECA's sales increased by 17 percent in 1995, and the firm announced growth rates of 23 percent in 1996, and projections of 13 percent in 1997 and 15 percent in 1998. MASECA imported 714,500 metric tons of corn in 1996.

These firms receive a subsidy from the government representing a significant percentage of total sales. In volume terms, the majority of tonnage sold is subsidized. MASECA received subsidies amounting to 49 percent of total sales in 1995 and 47 percent in 1996. The proportion is similar in the case of MINSA (Table 28).

Subsidies for tortilla consumers were initiated in Mexico City in the 1950s and extended to the entire country by 1972. In the early 1980s, these subsidies were transmitted through direct sales by Conasupo to the owners of the thousands of *nixtamal* units at discount prices. The other industries which used corn as an input had to purchase it directly from the producers at the going support prices. Conasupo would then compensate flour producers by an amount equivalent to the difference between the support price which accrued to corn producers, plus transport, storage and administrative costs, and the price at which Conasupo sold corn to the traditional dough producers or *nixtamaleros*.

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[79] There are nine states in Mexico (Aguascalientes, Colima, Chihuahua, Nayarit, Nuevo León, Quintana Roo, Sinaloa, Sonora and Tabasco) where the availability of subsidized maize is restricted. In these states practically all of the tortilla supply relies on industrial flour because, at current market prices, the costs of the traditional method make it unprofitable.

[80] *Grupo Industrial MASECA* (GIMSA) is the Mexican subsidiary of GRUMA, a holding occupying first place in corn flour and tortilla production in the United States, Mexico and Central America. GIMSA's sales account for 54 percent of GRUMA's operations and 80 percent of its gross income.

In 1990, new regulations for determining the payment of subsidies for the production and sales of *nixtamal* corn flour were issued. These directed that reimbursement to the flour companies would not discriminate among flour producers, thereby putting industrial plants on an equal footing with traditional *(nixtamal)* producers.[81] In 1996, further new regulations were approved[82] whereby Conasupo continues to sell corn at discount prices but traditional and modern producers of dough have the option of buying from the State-owned company or through private channels. In this last instance, they are entitled to a supplementary payment.[83] A new method of calculating the "indifference prices" and Conasupo's operations implies the convergence of domestic prices on international prices well before the transition period established in NAFTA expires.

Table 28 Government Subsidies to Corn Flour Industries

Thousands of Current Pesos				
Company	1993	1994	1995	1996
GIMSA	1,473	1,616	1,924	2,679
MINSA	491	730	1,034	–
Total	1,928	2,346	2,958	2,679
Thousands of Constant 1994 Pesos				
Company	1993	1994	1995	1996
GIMSA	1,537	1,616	1,425	1,477
MINSA	525	730	766	–
Total	2,063	2,346	2,191	1,477

Totals have been rounded up.

Source: Aserca.

Total subsidies to tortilla consumers amounted to more than NP$8 billion in 1996. Through this subsidy the price of tortillas in Mexico remained at NP$1.40 per kilo. According to the industrial producers of tortilla, in the absence of this subsidy, tortilla prices could reach NP$2.70 per kilo. The reduction in Conasupo's operations means that this State-owned firm maintains its regulatory functions, but these are carried out through the management of direct subsidies to the flour industry instead of the control of supply volumes.

In August 1997, the price of tortilla flour increased to NP$1.70 per kilo.[84] Conasupo is providing a strong subsidy to the flour industry. It is purchasing corn at NP$1,335 (mostly in the highly productive areas in the Northwest) and it is selling this corn to the flour industry at approximately NP$400 per ton. Conasupo is absorbing all financial charges. The price of tortillas has not been driven down by the availability of cheaper inputs for the flour industry (due to corn imports). Thus in rural Mexico, traditional corn producers have continued to engage in corn production in spite of the drop in prices for producers.

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[81] Payments were made every two weeks and were determined according to the difference between the price received by Conasupo from traditional dough producers and the so-called Integrated Cost of Maize (ICM) divided by physical conversion factor. The ICM was fixed at different levels according to the agricultural cycle, transportation costs, guaranteed prices, and seasonal factors.

[82] Decree which established a subsidy maize tortillo flour for human consumption (entered into force 1 June 1996). *Diario Oficial*, 31 May 1996.

[83] The supplementary payments accruing to producers are calculated on the basis of the indifference price (IP). The change in the reference price responds to the desire to allow the corn flour and traditional corn dough producers to purchase corn interchangeably in the national or the international markets. In the event of expenditures incurred in US dollars, the government subsidy shall cover interest payments for 60 days—30 days for transit of inventories and 30 days for storage, plus all other currency conversion expenditures.

[84] This was an increase of 20 *centavos*.

3. *Alianza para el campo*

The most recent government program for the agricultural sector is *Alianza para el campo* (AC). The program was launched in 1995 and is designed to operate between 1996 and 2000. Its goal is to increase productivity and competitiveness in the agricultural sector in the context of an open economy. The total budget of the program was US$250 million dollars in 1996.

Its objectives include:

- increasing net incomes for producers,
- maintaining growth rates in agricultural production higher than population growth,
- achieving a surplus in the agricultural trade balance and self-sufficiency in basic products,
- reducing regional disparities, and
- making a lasting contribution to efforts to eradicate rural poverty.

The program is designed to achieve these objectives by strengthening the flow of capital and technology to agriculture for the acquisition of machinery and tools to increase productivity, to reduce risk in rain-fed systems, to improve post-harvest management, and to diversify production. Under the program one-time payments are made directly to producers.

Some of the more important components of this program are the following:

- The *kilo por kilo* sub-program seeks to increase average productivity for corn, beans, rice and peas by encouraging the use of open-pollinated improved and certified seeds (provided by *Productora Nacional de Semillas*). In the *kilo por kilo* program, each kilogram of improved varieties, regardless of its market price, is exchanged for one kilogram of maize or beans of the producers' harvests. The program is aimed at producers who have not used these seeds in recent years but have the capacity to use them. Producers and regions targeted operate predominantly in the rain-fed cycle (spring-summer). It is expected that yields in maize production will be increased by 800 kilograms per hectare as a result of this program.
- Other components of AC are oriented towards greater investments in irrigation systems, as well as in the use of fertilizers and mechanized traction. The program provides up to 35 percent of total investment costs in new irrigation projects (up to NP$2,450 per hectare), while state governments provide an additional 10 percent. The total cost of this component is US$1,200 million. Purchase of machinery is also eligible for support: up to 20 percent of the cost of equipment (up to NP$20,000 per tractor) and 30 percent of costs for spare parts. In 1997, *Alianza para el campo* contemplated the purchase and repair of 11,450 tractors, benefiting 39,000 producers.
- The program also assists producers in establishing grazing land. The federal government will cover up to 40 percent and state governments up to ten percent of total investments in seeds, fence construction and other basic infrastructures. Planning and design for new projects related to livestock production are also eligible for support.

The program is geared toward prosperous farmers. For *campesinos*, *Alianza para el campo* offers programs in the states of Oaxaca and Guerrero, important sources of migrant laborers. Credit programs involving small, short-term loans with no collateral *(crédito a la palabra)* for production or for individual housing projects or for the purchase of goats and sheep offered through the of the Ministry of Social Development (Sedesol) provide another source of support. These programs are designed primarily to alleviate poverty.[85]

4. Reforms to Article 27 of the Constitution

In November 1991 several important amendments were introduced to Article 27 of the Federal Constitution. One key objective of the reform was to enhance the flow of capital to agricultural production in Mexico to encourage technical change and productivity increases that would increase international competitiveness. It was also thought that a clearer definition of property rights would bring about improved environmental management.

Four of the key reforms to Article 27 are as follows:

- The State was relieved of the obligation to provide petitioners with productive land. A special office was established to deal with the backlog of unresolved claims, and the legal passages which established the procedure for petitioners were deleted.
- *Ejidatarios* were given the right to sell, rent or use as collateral their plots of land. *Ejido* members were also given the right to form new associations with private investors. In joint ventures, *ejidatarios* were authorized to obtain T-type shares in exchange for their land.
- Private companies were given the right to purchase land in accordance with established legal limits. Under the new rules, a private company of at least twenty-five individuals can own a farm of up to 2,500 hectares of irrigated land, 5,000 hectares of rain-fed land, 10,000 hectares of good quality pasture land, or 20,000 hectares of forested land.
- Two new national institutions were created to regulate conflicts, arbitrate and settle agrarian conflicts—the Office of the Agrarian Attorney General and of the Superior Agrarian Court.

These amendments increased opportunities for land ownership by *ejidatarios* and attracted capital and investment to Mexican agriculture. The reform also created a market for land. At the time, some organizations expressed concern that the reforms would put poorer *ejidatarios* in the risky position of losing land offered as collateral in the case of foreclosure, aggravating rural poverty. These same groups asked the government to investigate existing land holdings to ensure that thousands of would-be petitioners would have the prospect of having land distributed to them. Most broadly, the 1991 amendment to Article 27 of the Constitution, allowing *ejidatarios* to sell or rent their land, has strengthened property rights and environmental management, while increasing the risks of rural poverty for others.

5. Credit and Banking Institutions

At the end of 1988 the Mexican financial and banking sector was reformed. The reform package included internal liberalization, the complete elimination of controls over active and passive interest rates, substitution of the requirements to maintain part of the reserves as a deposit in the central bank by liquidity requirements, and elimination of the regulations that directed credit toward certain productive activities.[86] Banks were privatized, the central bank acquired autonomy and the banking sector was opened to foreign capital.

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[85] The implementation of these programs appears to be rather uneven and resources do not always reach the producers in a timely fashion. For example, in parts of the state of Veracruz (Tlalixcoyan and Medellín, near the capital of that state), some producers lost crops as a result of delays in processing small loans for the purchase of fertilizer.

[86] Previously banks were required to keep a certain percentage of their reserves under custody of the central bank. The reforms eliminated this obligation and instead established requirements regarding asset composition.

The development banks were also reformed. By 1991 they were restricted to second level operations as a risk reduction measure. Subsidies through credit were virtually eliminated, and each investment project was to be evaluated on a case-by-case basis aimed at the recovery of invested resources. Prior to this reform, the main development bank servicing the agricultural sector was Banrural. In 1989 the Banrural portfolio was reorganized and irretrievable loans were transferred to *Programa Solidaridad* where they were reclassified under more lenient or flexible criteria.[87] The policies for loan authorizations were changed and only producers with the capacity for good administrative organization became eligible.

The size of the non-performing portfolio has affected the agricultural sector's development banks. In 1993 a special program was created to restructure this non-performing portfolio by rescheduling debts from 5 to 15 years and initiating a special service for technical assistance. An additional program was set up in 1994 and NP$32,000 million of non-performing loans were rescheduled. In 1997 the problems still exist. In real terms (constant 1993 prices), the value of all non-performing loans in agriculture increased from NP$2.4 billion to NP$7.6 billion in 1994. By 1997, the expansion of the non-performing loans in agriculture had reached NP$8 billion.

In general, the level of credit for agricultural producers is at an all-time low. The share of agriculture in total credit for the private sector has been cut in half since 1981 (see Table 29). In real terms the amount directed to agriculture is comparable to levels at the beginning of the 1990s. At the same time, many producers are facing the challenges brought about by external competition.

Data exist on a more disaggregated basis for the Banrural system of banks, one of the two most important sources for credit to corn producers. Table 30 shows that between 1980 and 1994, the share of corn producers in Banrural's operations rose from 23 percent to 42 percent. But loans for corn producers experienced a steep decline: in real value terms (constant 1993 prices) they dropped from NP$3 billion in 1980 to NP$1.5 billion in 1994.

The decline in the availability of credit is more pronounced for corn producers operating under rain-fed conditions than for those using irrigated systems.[88]

Another source of credit and loans for producers is Pronasol. Its short-term loans have traditionally been low (NP$1,098 per loan) but have had the advantage of not requiring interest payments or collateral. The 1994 *ejido* survey revealed that Pronasol was used more than Banrural and the commercial banks. The total amount made available to the *ejido* sector represents around 15 percent of total loans. The 1994 *ejido* survey recognizes that the lack of credit for the *ejido* sector is an important factor affecting modernization in that sector.

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[87] *Programa Solidaridad* is an anti-poverty program.

[88] Producers in need of credit have resorted to authorizing Procampo authorities to draft checks payable to suppliers of inputs. In other cases, they resort to local moneylenders at high interest rates.

Table 29 Total Credit for Agriculture in Mexico, 1981–1996

Commercial and Development Banks	1981	1985	1990	1992	1993	1994	1995	1996*
(Figures in millions of 1993 pesos)								
Total Credit	225	366	357	504	583	814	694	615
Commercial	106	180	235	379	437	576	479	439
Development	81	185	122	125	146	237	214	176
Total Credit								
Agriculture	25	23	30	36	39	47	34	
Commercial	10	11	19	27	29	37	24	
Development	14	11	11	8	10	9	9	
(Percentages)								
Total Credit	100	100	100	100	100	100	100	100
Commercial	55	49	66	75	75	71	69	71
Development	45	51	34	25	25	29	31	29
Total Credit for Agriculture								
(Share in total agricultural credit)	11	6	8	7	7	6	5	5
Commercial	50	49	62	76	74	77	72	71
Development	50	51	38	24	26	23	28	29

*Figures for January-September. Balance for 31 December of each year.
Figures cover credits to private sector only. All figures have been rounded.

Source: Anuario estadístico del VI Informe de gobierno, *1994 and Banco de México.*

Table 30 Credit for Corn Producers by Banrural System

Year	Total	Total Corn	% Variance	Irrigated	% Variance	Rain-fed	% Variance
1980	3.4	0.8		0.07		0.72	
1982	4.3	1.4		0.16		1.27	
1984	4.5	1.3		0.18		1.12	
1986	4.6	1.5		0.25		1.28	
1988	5.9	2.0		0.47		1.59	
1990	2.5	0.5	-64	0.13	31	0.37	-72
1991	1.8	0.4	-11	0.19	42	0.25	-30
1992	1.6	0.5	13	0.22	14	0.29	13
1993	1.6	0.6	25	0.42	90	0.22	-23
1994	1.5	0.6	-2	0.48	13	0.15	-32

Billions of 1993 pesos.

Source: Economic Commission for Latin America.

6. Insurance

Table 31 shows that the availability of insurance for all crops has dropped, but in the case of corn (particularly in rain-fed production) insurance coverage has been virtually eliminated.

Between 1965 and 1990, the *Aseguradora Nacional Agrícola y Ganadera* (Agricultural and Cattle National Insurance Company—Anagsa) was responsible for providing insurance services to Mexican producers. Crop, life, and risk insurance on all Banrural loans were its main line of activity. Crop insurance covered risks such as weather, disease, and fire. The insurance included payments for all expenses incurred up to the time of the crop's destruction. In 1989, 75 percent of all requests for indemnification corresponded to Banrural loans that could not be recovered.

A new organization was created in 1992—*Compañía Mexicana de Seguro Agrícola* (Mexican Company for Agricultural Insurance—Agroasemex). This company remains active and its operations are not related to Banrural loans. Clients are carefully selected on the basis of their commercial potential. Producers received a subsidy of up to 18 percent of the insurance cost in 1991. This subsidy has now been increased to 30 percent. Nevertheless, not all Mexican producers have guaranteed access to fully reliable insurance coverage.

Table 31 Agricultural Insurance by Crops and Cycles, 1985–1995

	Total Surface Covered (Cycle and Crop, in thousands of hectares)									
	1985	1987	1988	1989	1990	1991	1992	1993	1994	1995
Irrigated	1979	1817	1758	1411	515	241	325	242	301	176
Rice	103	60	64	81	9	4	4	3	8	7
Beans	47	110	120	84	27	8	17	21	18	4
Corn	226	260	330	213	41	26	73	122	136	41
Wheat	665	452	424	430	158	38	91	64	71	72
Sesame	19	20	10	5	2	1	1	0	1	0
Cartamus	18	34	111	62	20	1	1	1	7	1
Sorghum	285	310	265	220	74	18	30	10	11	7
Cotton	138	125	132	71	21	29	2	1	13	34
Soy	250	206	73	155	45	38	26	18	34	10
Barley	8	15	5	7	1	1	1	2	2	0
Others	220	225	224	83	117	77	79	N.A.	N.A.	N.A.
Rain-Fed	5267	5777	5284	3877	1068	318	323	133	128	145
Rice	119	95	80	100	11	6	4	1	4	3
Beans	699	913	960	671	212	20	14	24	21	28
Corn	2470	2919	2668	1719	334	81	67	52	55	31
Wheat	120	119	75	77	28	1	2	8	9	6
Sesame	73	64	59	29	11	1	1	0	0	0
Cartamus	190	182	154	87	28	1	2	3	2	0
Sorghum	994	883	644	536	180	38	58	40	32	72
Cotton	2	0	18	10	3	7	1	0	1	0
Soy	79	72	26	59	17	4	5	2	3	3
Barley	43	72	30	48	4	3	5	3	1	2
Others	478	458	570	541	240	156	164	N.A.	N.A.	N.A.
Total Surface	7246	7594	7042	5288	1583	559	648	375	429	321

Source: Aseguradora Nacional Agrícola y Ganadera *(until 1988) and Agroasemex (1989–1995).*

7. Agricultural R&D and Technical Assistance

Between 1987 and 1994, funds earmarked for agriculture in the national budget for research and development in science and technology dropped from 16 percent to seven percent. In 1995, total government transfers to the *Instituto Nacional de Investigaciones Forestales y Agropecuarias* (National Institute of Forestry and Agricultural Research—INIFAP), the principal research center in Mexico for agriculture, livestock and forestry, amounted to US$48 million. That year, total R&D expenditures in agriculture represented one percent of agricultural GDP (OECD 1997).[89]

Total R&D expenditures for the Federal Government are shown in Table 32.[90] In percentage terms the estimated level of total R&D expenditures for 1997 is equivalent to the level in 1993. In absolute terms it is slightly higher.

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[89] Separate figures for agricultural R&D in all universities and public laboratories are not available.

[90] Total R&D expenditures remain low by international standards, and UNESCO's recommended level of 1 percent of GDP appears unattainable in the short or medium term.

Table 32 Total National and Agricultural R&D Expenditures, 1988–1997

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Total R&D expenditures as percent of GDP	0.25	0.25	0.28	0.33	0.32	0.37	0.41	0.35	0.33	0.37
Federal R&D Expenditures in Agricultural Production										
Current pesos	144	326	248	352	322	389	460	376	577	623
Constant 1993 pesos	314	551	325	384	330	389	447	303	317	N.A.
As percent of agricultural GDP	0.48	0.84	0.47	0.54	0.47	0.54	0.61	0.41	0.42	N.A.

Source: Author's calculations based on data from Ernesto Zedillo, Anexo del Tercer Informe de Gobierno 1997.

Recent R&D allocations in the agricultural sector have fallen sharply in real terms. This is aggravated by the virtual absence of technical assistance, as the government has reduced its role as the main provider of technical assistance.[91] Fiscal expenditures for agricultural development are a fundamental item in the macroeconomic regime.[92]

In order to ensure a balanced budget over the past decade, public expenditures in several key areas have been reduced. Table 33 presents relevant data on public expenditures for agricultural development since 1980. Between 1980 and 1995, the share of total public expenditures for agricultural development decreased from 11.9 percent of the total federal budget to eight percent. This decrease must be considered in the context of a declining level of overall federal expenditure. Comparing public expenditures in agriculture (including agrarian reform and regional development), in real terms, there has been no increase between 1985 and 1995. The increase in 1994 was probably due to an abnormal election year. In any event with the 1995 recession and the effect of the drop in oil prices in 1998, these levels will probably remain either stagnant or may decline.

Table 33 The Share of Agriculture in Total Public Expenditures, 1980–1996

	1980	1985	1988	1990	1992	1993	1994	1995	1996
Total Primary Federal Budget	116	212	247	203	182	120	142	109	99
Agriculture and Hydraulic Resources	13	9	5	5	8	7	12	9	9
Agrarian reform	0.9	0.7	0.5	0.4	1.2	1.5	1.5	0.8	N.A.
Regional Development and *Solidaridad*	–	5.8	4.0	4.0	6.5	7.3	7.4	5.5	N.A.

Levels in millions of 1993 pesos.

Source: Sexto Informe Carlos Salinas de Gortari *1994, 1er Informe Ernesto Zedillo 1995.*

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[91] The *ejido* survey of 1994 identifies the withdrawal of government and official institutions from this type of activity. The survey suggests that the private sector has taken up a more active role in all aspects of technical assistance including access to improved seeds and chemical fertilizers and pesticides (see Gordillo et al. 1994, 5.4–5.5), but it does not distinguish between technical assistance and the marketing services of the private suppliers of these inputs.

[92] Levy and van Wijnbergen (1992) suggest that the need to further increase these expenditures, through subsidies, is a NAFTA-related consequence.

The 1998 federal budget sent by the Executive to Congress for approval has earmarked NP$31.2 billion for agricultural development, representing an additional decrease in real terms of 2.69 percent. Indeed, if the target for inflation (12 percent) is not met, the share of funds directed towards agricultural development in the federal budget will decrease from 5.6 percent to 5.1 percent.[93]

Similarly, the level of subsidies earmarked for agriculture in Mexico is comparatively low compared with other OECD countries. Data on producers' equivalent subsidies of OECD countries reveal that Mexico applied agricultural subsidies worth US$2.1 billion in 1996 (see Table 34). In 1995, Mexican subsidies directed towards agriculture amounted to only US$300 million compared with US agricultural subsidies of US$62.4 billion.[94] These levels amounted to 13 percent and 16 percent of total agricultural value in Mexico and the United States, respectively.

Table 34 OECD Countries: Total Transfers Related to Agricultural Policies

	1986–88	1994	1995	1996
European Union	114.1	128.5	138.6	120.3
United States	68.2	76.4	62.4	68.7
Japan	62.5	87.2	100.5	77.4
Turkey	5.5	7.8	12.5	13.8
New Zealand	0.4	0.2	0.3	0.2
Poland	0.4	3.1	3.9	5.7
Mexico	6.1	8.5	0.3	2.1

Billions of US$.

Source: OECD, Agricultural Policies in OECD Countries *1997.*

B. Production, Management and Technology

The increasing production of maize in Mexico, despite falling prices, can be traced to a number of factors. Relevant factors include maize's high price relative to potential substitute crops; corn's relatively high NAFTA protection; strategies of modernization whereby efficient producers on irrigated lands use technologies, hybrids and mechanized agriculture; and the poorer producers' expansion of cultivated production on more marginal lands to maintain overall income. Producer strategies—both of modernization and traditional expansion—thus exert an autonomous impact that has offset price reductions with increased production. However, the particular technologies associated with the modernization strategy and the stress on marginal lands from traditional expansion, together could offset potential environmental benefits.

Some studies suggest that the structure of agricultural trade that would emerge from NAFTA would encourage liberalization of field crops in Mexico and horticultural reform in the United States. This would lead to an increase in exports by the United States of products that are land- and capital-intensive—such as grains, oil seeds, and meat products—as well as of products that are better produced in northern climates, such as stone and pome fruits. Mexico, on the other hand, would increase its exports of labor-intensive vegetables, fruits, and nuts, as well as products that are better suited to southern climates, such as coffee and tropical fruit. (Hufbauer and Schott 1993, 47; de Janvry 1996, 6.)

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[93] There has been some speculation as to the reorganization of budgetary items and its effect on appropriations for the sector. But appropriations for this sector suffered a drop in real terms of more than 25 percent.

[94] The low Mexican figure is due in part to the peso crisis of 1994.

Other analyses of the effects of NAFTA on corn production in Mexico generally offer three conclusions. First, price reductions would ensue from increased trade liberalization in corn. Second, these price reductions would bring about the release of resources (labor, land and capital) from the corn-producing sector. Third, NAFTA-induced price reductions would not affect producers for household consumption, and consumers in rural areas (many of them also producers) would benefit from the reduction in corn prices.[95]

In practice, corn producers in Mexico will continue to face competition from imported yellow corn that is treated as white corn even though in the international markets white corn prices are 20 to 25 percent higher. This difference is not taken into account in NAFTA's schedules. The downward trend in prices is strengthened by the increase in NAFTA-related imports. Prices in real terms dropped by approximately 40 percent between 1991 and 1995. This trend may well continue as the tariff-free quota expands (Table 20). Moreover, given lack of support from Conasupo, low increases in Procampo payments, and the scarcity of credit, crop insurance, and technical assistance in many regions of Mexico, some domestic producers will sell their corn at prices that are below the international price.[96]

Data on the profitability and competitiveness of corn producers in Mexico presented in Table 12 is based on 1990–1991 prices. These prices have since fallen by over 30 percent in rain-fed systems. At the same time, costs have increased as subsidies in agrochemical inputs have been eliminated and inflation has risen.[97] If the data in Table 12 were updated they would most likely show that only around 20 percent of producers responsible for over 51 percent of total production remain profitable. This is the only group remaining to supply Mexico's domestic market for corn. Thus, total imports could reach or even surpass 50 percent.[98]

Mexican corn producers are trying to adjust and will continue to do so through important changes in levels and methods of production. In 1994, corn accounted for more than 66 percent of the gross value of Mexico's agricultural production, well ahead of its nearest competitors.[99] Between 1986 and 1990 corn accounted for 57 percent of total agricultural production in Mexico. This share increased to 63 percent between 1991 and 1993.

Not only has corn remained the most important crop in Mexico but there has been a steady increase in production since 1991 (Table 35). In 1991, total national production of corn was 14.25 million metric tons. In 1995 it rose to 18.31 million metric tons. This high level of production was largely maintained in 1996 with a total of 18 million metric tons. Average yields remained stable and in some cases declined marginally between 1993 and 1994 when yields dropped from 2.2 to 1.9 metric tons per hectare.

There are a number of reasons for this increase in production in the face of declining prices. First, relative to other crops, such as rice, wheat and sorghum, the price of corn remained higher for most of this period.[100] Thus, corn continued to be profitable for producers with the highest yields.[101] These include producers in such regions as north-central Jalisco, southern Nayarit, Sinaloa, parts of Chiapas (La Frailesca), the state of México, Tamaulipas and Veracruz.

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[95] These issues are highlighted in Levy and van Wijnbergen 1992, de Janvry, Sadoulet, Davis and Gordillo 1995, Gordillo et al. 1994, FIDA 1993.

[96] In some cases, producers find themselves in need of cash, and their produce is, if not highly perishable, a source of storage costs. Their position is that of a disadvantaged party in a buyers' market. In some cases, producers will sell their corn at prices that are 10 to 20 percent below the indifference price (international price plus transportation and costs of introduction).This information was generated by a visit to corn-producing areas in Oaxaca and Michoacan. The information was also corroborated by personal communication from Jubenal Rodriquez, ANEC.

[97] Rates of inflation were 52 percent and 25 percent in 1995 and 1996 respectively.

[98] Were this to occur, Mexico could become the third largest corn importer in the world behind China and Japan.

[99] Beans and wheat account for 12 and 11 percent respectively. Rice, sorghum and soybeans come next, while other crops, including horticulture, are responsible for a modest 6 percent of total gross value of agricultural production.

[100] The only price that remained higher than corn was that of beans, but this crop is not a competitor of corn.

[101] An additional explanatory variable may be the increase of 20 *centavos* (2.5 US cents) in the official price of tortillas in August 1997.

Second, there was a return to production in regions where corn had long-since ceased to be the most important crop. While imports of such grains as sorghum, wheat and soybeans increased, those of corn practically disappeared as Mexico regained self-sufficiency in this grain. The other basic grains lost virtually all protection vis-à-vis external competition, while corn retained protection under the tariff set in NAFTA's schedule.

Evidence points to two important trends in the production of corn. First, in the modern sector, expanded production has occurred on irrigated land using technologies and techniques including hybrids and mechanized agriculture and profiting from relative price differentials in 1994-1995. Second, poorer producers have also expanded their production, although at a slower rate, using traditional technologies on poorer land.

Table 35 Volume of Production for Mexico's Main Crops, 1991–1996

Crops	1991	1992	1993	1994	1995	1996
Basic Grains	*20,039*	*21,663*	*23,282*	*24,125*	*23,405*	*23,082*
Corn	14,252	16,929	18,125	18,236	18,306	18,005
Wheat	4,061	3,621	3,582	4,151	3,458	3,308
Beans	1,379	719	1,288	1,364	1,274	1,388
Palay Rice	347	394	287	374	367	381
Oilseeds	*1,157*	*708*	*627*	*783*	*695*	*903*
Soya	725	594	498	523	190	162
Cotton	307	50	42	187	369	551
Cartamus	88	41	64	64	114	165
Sesame	37	23	23	9	22	25
Other grains	*4,888*	*5,903*	*3,122*	*4,008*	*4,694*	*5,398*
Sorghum	4,308	5,353	2,581	3,701	4,193	4,862
Barley	580	550	541	307	501	536
Total	26,084	28,274	27,031	28,916	28,794	29,383

Thousands of metric tons.

Source: Sagar, Boletín de información mensual del sector agropecuario *(several years).*

The share of corn produced on irrigated land has increased. There has not been the switch to horticulture on irrigated land. Rather, much irrigated land has become used for high-yield operations for corn. Yields have increased as a result of modernization and use of irrigation.

In 1994, the balance between rain-fed systems and irrigated systems shifted. Between 1990 and 1994, the share of total corn production from rain-fed systems declined from 77 percent to 55 percent, while the share of irrigated production increased from 23 percent to 45 percent. Such an allocation of irrigated land with high yields to corn production was not expected. However, trade protection for corn and beans had been maintained, while the trade regime for the rest of cereals and oleaginous crops was liberalized.[102] Corn's relatively high price vis-à-vis alternative crops may explain why those producers elected to produce corn instead of other grains such as wheat, soybeans, or sorghum (Figure 10).

The regions that showed renewed interest in corn production were those where irrigated land was previously allocated for other crops. Producers with high yields and the potential to increase production responded to this opportunity in states like Sinaloa or parts of Nayarit and Tamaulipas and expanded their production of corn. These are the same producers capable of producing alternative crops with higher commercial value.[103]

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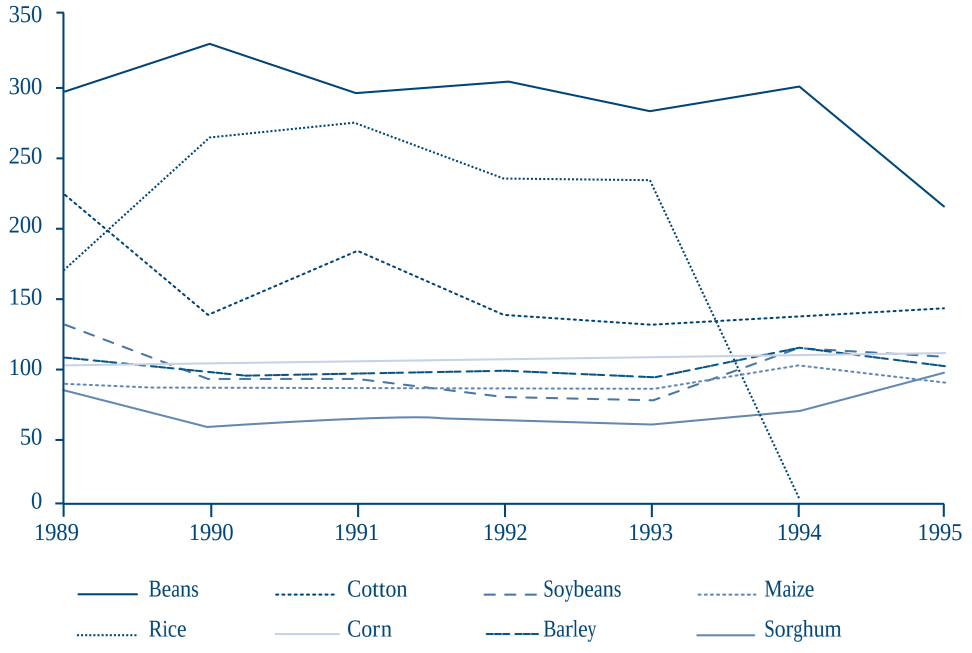
[102] Appendini (1996).

[103] Appendini calls this "regressive crop restructuring."

Cultivated surface dedicated to corn production has increased. Between 1994 and 1996 the cultivated surface dedicated to corn production in the Spring–Summer cycle increased from 6.9 to 7.2 million hectares at the national level.

Figure 10 Relative Prices to Maize: Average Rural Prices in Constant 1994 Pesos



Source: Author's calculations with data from Consejo Nacional Agropecuario.

Table 36 shows cultivated surface at the national level increased by a significant amount between 1990 and 1995, a period marked by the policy reforms which became associated with the NAFTA corn regime. However, yields during that same period increased at a significantly lower rate. Discounting the states of Sinaloa and Sonora, where yields increased at a greater rate, the national average change in yields is even lower.

This study considers annual average changes between 1990 and 1995. It shows that there is a reduction of yields in thirteen states responsible for 37.5 percent of the total number of corn producing units. In eight states, increases in cultivated surface exist alongside reductions in yield.[104] In an additional six states increases in cultivated surface also bring about increases in yields but those increases are below the national average.[105] More than 62 percent of the total number of corn-producing units operate in these 19 states. Data in Table 36 suggest that there is no clear trend to reduce pressure on marginal lands.

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[104] Baja California, Colima, Jalisco, Quintana Roo, San Luis Potosí, Tabasco, Tamaulipas and Yucatán.

[105] Campeche, Durango, Morelos, Nayarit, Oaxaca, Veracruz.

Table 36 Changes in Cultivated Surface, Production and Yields by State, 1990–1995

State	Average Increase Cult. Surface	Average Increase Harvested Surface	Average Increase in Production	Average Increase in Yield	% of Total # of Corn Producing Units	% of Total # of Units up to 5 ha
Aguascalientes	-4,385	-3,016	2,268	-0.080	0.49	36.6
Baja California	177.6	325.2	610.2	-0.087	0.04	18.7
Baja California Sur	-96.8	-95.4	2,768.2	0.357	0.05	32.5
Campeche	10,542	-6,831	-7,575.4	0.045	1.04	45.0
Coahuila	2,487.8	-1,948.4	-310.6	0.063	1.20	59.4
Colima	1,140	1,260.8	3,076.8	-0.011	0.26	22.1
Chiapas	42,691.8	41,133.2	124,130.6	0.067	9.22	50.7
Chihuahua	1,145	-21,205.6	-26,420.4	0.094	2.36	44.1
Distrito Federal	-534.2	-574.6	-1792	-0.080	0.43	97.2
Durango	1,732.4	2,712.4	11,364.4	0.039	2.18	43.0
Guanajuato	1,279.8	-5,273.6	31,514.8	0.108	4.00	46.5
Guerrero	6,130.4	5,722.8	56,779.6	0.095	6.15	74.0
Hidalgo	-1,354.8	-4,230.2	-6,716.6	0.004	5.42	83.5
Jalisco	1,416.4	6,001.6	980.4	-0.027	3.93	36.2
México	-10,580.2	-12,834.8	-50,134.6	-0.007	8.97	91.5
Michoacán	14,787	19,212	77,660.2	0.072	4.74	59.9
Morelos	726.8	726.8	4,017.8	0.052	0.92	78.0
Nayarit	5,815.2	6,185.6	16,278.2	0.003	1.08	45.1
Nuevo León	6,704	-3,339.6	-1,284.2	0.094	0.95	46.1
Oaxaca	19,543.4	29,951.6	53,550	0.035	10.22	76.3
Puebla	-300.8	4365.8	-2656.2	-0.019	9.66	83.0
Querétaro	3,456.6	2,262.4	15,803.4	0.131	1.42	61.2
Quintana Roo	5,830.8	-4,922.6	-4,792	-0.055	0.86	59.1
San Luis Potosí	18,115.2	1,036.2	-7,220.8	-0.057	3.93	59.3
Sinaloa	51,377.6	52,330.2	341,991.4	0.507	1.46	27.7
Sonora	12,159.6	12,116.6	67,615.8	0.277	0.51	33.4
Tabasco	11,290	4,928.8	1,566.6	-0.100	1.17	33.5
Tamaulipas	28,402.2	24,511.2	31,995.6	-0.094	1.43	22.5
Tlaxcala	-770	-245.4	-1,679.6	-0.008	2.14	85.5
Veracruz	11,724.2	14,739.2	51,631.8	0.047	9.03	44.3
Yucatán	4,730.4	-7,693.2	-9,144.8	-0.026	1.87	75.4
Zacatecas	-12,960.8	-21,008	-32,393.2	-0.028	2.88	25.8
National Total	232,423.6	136,304	743,483	0.059	100	54.5

Source: Anuarios estadísticos de la Sagar, *1990–1995.*

In terms of volume, corn production has also increased in states such as Guerrero and Oaxaca at rates of 9 and 14 percent respectively per year between 1990 and 1995. In those states, the majority of producers are small, poor farmers using traditional technologies and operating on sloping lands in poor soils. In these states, the increase in production is not the result of increases in yields or efficiencies, as is the national profile, but due to increases in the amount of land under cultivation.

In Oaxaca, for example, the cultivated surface area increased from 503,586 to 583,076 hectares between 1991 and 1995, but yields remained almost stable (1.1 t/ha and 1.3 t/ha) for those two years. Only 25 percent of the increase in production in Oaxaca resulted from higher yields. Sixty-five percent of the growth resulted from an increase in the amount of land under cultivation (Table 37). Some traditional producers have been hurt by the general evolution of the economy over the past fifteen years and have had no real alternatives but to extract as much as possible from their land. Data from the 1994 *ejido* survey suggest that *ejidatarios* operating under rain-fed conditions have experienced a deterioration of their technological base (Gordillo et al. 1994; de Janvry et al. 1995a). Increasingly these producers must not only rely upon their land, but on their labor as well.

Table 37 Sources of Production Growth in Oaxaca, 1990–1995

	Sources of Δ P			
	Δ P	Δ Y	Δ S	Δ Residual
National Total	3,717,417	2,128,273	1,359,111	230,033
Shares (%)	100.0	57.3	36.6	6.2
ROG P	25%			
Oaxaca	267,750	66,411	173,644	27,694
Shares (%)	100.0	25.0	65.0	10.0
ROG P	59%			

Metric tons and percentages.

Source: Sagar, Anuario estadístico de la producción agrícola.

In the face of increasing imports and declining prices there are some key strategic responses underway in the corn sector that rely on production techniques and technologies.

1. Modernization of Corn Production—Technologies and Techniques

Some producers have the potential to modernize corn production, thereby increasing yields and profitability. Further reductions in the price of corn could be offset by significant increases in yield and thus profits. In order to achieve this, these producers will require technical assistance, credit and, in some cases, significant investment in infrastructure. Modernization can occur through the adoption of a variety of technologies and practices. It is viable in regions where conditions are good and yields are competitive (good rain-fed or irrigated systems in deep, well-drained soils).

Among the technologies or techniques that might be adopted through modernization are conservation techniques, monoculture, the use of improved varieties and hybrid seeds, the use of pesticides and fertilizers and increased reliance on mechanized traction. Other items include live walls, alley cropping, vetiver grass, green fertilizers, cover crops, crop rotation, intercropping and practices such as contour plowing. These technologies and practices have different economic and environmental profiles. A number of these technologies or practices can increase productivity. Some are relatively positive for the environment. Some are expensive.[106] Some require the existence of strong social institutions and community involvement to operate effectively. For example, implementing soil and water conservation practices may not require heavy capital outlays but do require labor-intensive maintenance.

a. Minimum or No-Tillage

A number of conservation techniques may be part of a strategy of modernization. They are available to producers to, among other things, preserve soil and prevent erosion. Among them are minimum or no-tillage techniques, or vegetative techniques. Minimum or no-tillage techniques can, through decreased tractor use, reduce the energy input into corn production by seven percent and produce yields as high as or higher than conventional plowing and disking methods

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[106] Low prices for corn may discourage investment in long-term projects, adoption of conservation practices and/or the encouragment of poor management practices (Pimentel, Allen et al. 1993).

(Raven et al., 701).[107] Some studies show important increases in yields at the same time as erosion is reduced.[108] This is particularly important on sloping agricultural land.

These techniques may necessitate the increased use of pesticides and herbicides because secondary tillage for weeding purposes is eliminated, and (in some cases) coverture is left behind to rot at the end of the harvest. These additional chemical inputs can accumulate in soils and affect surface water and aquifers through runoff and filtration. In addition, minimum or no-tillage systems require that residues and leaves be left to rot on the fields to cover the soil. This can impede the free-flow of water for irrigation through the furrows in a plowed field. Additional labor is required to address the problem and avoid wasting water. There are tillage practices which maximize rain infiltration *in situ* by building small pool-like systems in each row (*surco*). This can be done by mechanized systems or animal traction (Turrent 1996, 94).

b. Vegetative Techniques—Terracing

The adoption of vegetative techniques does not require large-scale operations. Vegetative techniques include the construction of living wall terraces, alley cultivation, small furrows and walls and the use of raw materials such as trees, shrubs and/or grasses. Terraces help reduce loss of topsoil even when steeply sloping land is cultivated. These and other structures are the only means by which sloping terrain can be modified. In cases where these structures are built with labor-intensive techniques, the supply of labor is a critical element for the modification of the physical landscape to increase productivity and for soil conservation. Erosion is more rapid and severe on sloping land unprotected by terraces.[109]

Disciplined construction of terraces along slope contours is less practiced today. Hastily built terraces on the upper slopes often begin to give way sooner than carefully constructed terraces. These ill-designed terraces contribute to landslides that frequently damage more cropland and sometimes destroy entire villages. Innovative terracing systems are of vital importance in regions where slopes are steep (Turrent 1996, 94–95) and can help retain soil components, increase sedimentation and infiltration, minimize runoff, and structurally secure the soil. Thus, they can help forestall rilling and gullying of land and can prevent underground structures from being degraded through tunneling. In many cases, the vegetative elements of these structures involve chemicals unpalatable to pests. The rates of diffusion of these techniques depend not so much on their technical parameters, but on the way in which they can be integrated into community and local farming practices. The labor required to maintain these structures is critical.

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[107] In this form of tillage, dead plant material that remains on the ground after the crop is harvested is left on or near the surface of the soil, rather than being plowed deeply into the ground as in traditional tillage, or burnt as part of conventional cultivation practices. The dead plant material at the surface of the soil helps to keep moisture within the ground and protects the soil from erosion.

[108] In a study in La Fraylesca region, soil losses due to hydric erosion were reduced by 84 percent (López Martínez 1993). See also Villar Sánchez 1996 in La Fraylesca, and Cadena Iñiguez 1995, for the Sierra Madre of Chiapas.

[109] See Pimentel 1993 and references therein.

c. Contour Plowing

This type of tillage affects loss of soil through erosion by wind and rainwater.[110] When furrows are plowed in an uphill-and-downhill direction, water tends to flow down the furrows, carrying away small particles of the top layers of soil as it flows. By plowing across the slope, the water stays in the furrows and is more readily absorbed into soils instead of running off. In this type of tillage the furrows follow the natural contours of the land—contour plowing. In regions where contour plowing is abandoned, erosive processes may set in. This is a very relevant point where migration may cause the abandonment of this practice. In many regions in Mexico, where slopes are important, contour plowing helps prevent rain-induced erosion. Without contour plowing, when the furrows of the last season disappear there is nothing to slow down the course of water and loss of topsoil sets in.

Contour plowing is important in Mexico, where 67 percent of agricultural land has a slope of 4 percent or more and is farmed in rain-fed conditions. Plowing land and tillage for the purpose of eliminating weeds under the predominant topographical conditions in Mexico, must follow the contours of slopes in order to avoid aggravating erosion.[111]

In Mexico, contour plowing is not compatible with large and unwieldy machinery because this kind of equipment is unable to follow contours on sloping cropland.[112] There are no studies on trends in the modern corn sector in Mexico regarding the use of capital equipment in larger units of production. Scale is important and even the large Mexican farms may not compare with the size of US production units. However, farmers trying to benefit from contour plowing on sloping croplands may face the same problems US units have encountered. Additional pressure may come from specialization and trends to diminish crop rotation. Continuous monoculture will cause further soil degradation. In the tropics, where rainfall is abundant, these negative tendencies will be magnified.

The maintenance of contour plowing can be labor intensive. After heavy rains, the walls of furrows that have been destroyed or damaged must be repaired quickly or they risk being destroyed. If contour plowing reduces the risk of erosion, its absence, even over a short period of time, may increase that risk. Abandoning cultivation altogether may be beneficial from a restricted environmental point of view because topsoil may be restored. But this depends on rain and wind patterns. It also depends on the grade of the sloping ground.

The kind and amount of cultivation between the rows of growing crops is determined essentially by the character of the soil. Heavy, waterlogged soil benefits by the stirring up and aeration that cultivation provides. On the other hand, hard, caked soils may require cultivation to permit them to absorb the moisture that the crops need.

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[110] Plows are designed for different purposes: from the simple cutting of a furrow through the ground to the complete turning over of soil, usually to a depth of 15 to 20 cm. In certain areas and for certain purposes the plow is replaced as a primary tillage instrument by various types of tools that scrape the surface of the ground without digging deeply into it. In most areas, such implements are employed merely to break up and pulverize the soil after plowing. Different crops have different requirements in terms of the structure of surface soil. Corn does require rather well broken-up surface soil, but there are other crops that require even finer structures.

Deep plowing and subsequent harrowing are necessary in areas where the soil is compact and impermeable to water and plant roots. Excessive tillage may result in the deterioration of soil structure, particularly if performed in wet soil. This problem is more acute in finely textured soils than in sand and loamy soils, which normally require less tillage. Climate also plays its part in determining not only the amount but also the time of tillage (Strahler and Strahler 1989). In humid areas, tillage should be limited to times when no great amount of rainfall is expected, for newly-tilled fields are susceptible to water erosion. In arid or subhumid areas, on the contrary, land should be tilled before periods of anticipated rainfall so that the ground can absorb the maximum amount of water.

Among the secondary but important benefits of tillage is aeration resulting from pulverization. This aeration not only provides a freer circulation of oxygen and water but also results in increased biological activity in the soil, including that of organisms which fix atmospheric nitrogen. Tillage contributes to the health of plants by inhibiting plant diseases and by discouraging the development of various types of insects that harm plants.

[111] For decades, public investment in infrastructure in this kind of land has lagged behind real needs (Turrent 1993, 81).

[112] In the United States, the trend after World War II was to shift towards larger farms, greater mechanization and regional specialization. Accordingly, bigger machinery was introduced and contour plowing modified to accommodate it; terraces, shelter-belts, and hedgerows were removed because they restrict the operation of large machinery (Pimentel, Allen, et al. 1993, 286).

d. Organic Matter

Organic matter is important in maintaining good physical conditions in the soil. It contains the entire soil reserve of nitrogen and significant amounts of other nutrients, such as phosphorus and sulfur. Soil productivity is affected markedly by the organic matter balance maintained in the soil. Because most of the cultivated vegetation is harvested instead of being left to decay, organic materials that would ordinarily enter the soil upon plant decomposition are lost. To compensate for this loss, crop rotation and artificial fertilization are used.

Organic fertilizers such as manure and compost also increase organic contents of soil. The combining of soil with animal manure serves as a source of various complex organic compounds that are important in the growth of plants. Compost consisting of mixtures of dead vegetable and animal matter has the same purpose.

e. Intercropping

Another technique is intercropping (including annual and perennial systems). Intercropping is an agricultural strategy where several crops are grown simultaneously, with beneficial economic and environmental consequences. One example is provided by the case of kidney beans (Phaseolus vulgaris), the production of which is closely related to the strategies of corn producers in Mexico. Beans are frequently sown in association with corn by many traditional producers. The dietary complementarities of the bean-corn couple performs a critical function in the daily livelihood of peasant families. In addition, the nitrogen fixation properties of the bacterium Rhizobium, which occurs naturally in the root nodules of bean plants, plays an important role in maintaining soil fertility. Consequently, in many cases where crop rotation is difficult for traditional corn producers due to the highly unpredictable precipitation regime, intercropping is a good substitute.

Finally, innovative terracing systems, such as live walls and alley cultivation, are of vital importance in localities where steep terrain is predominant (Turrent 1996, 94–95). Each technique has different requirements and feasibility conditions. In general terms, they require capital and labor, and will thus compete under normal circumstances with the objective of minimizing costs per unit of output. They also require close monitoring in order to carry out necessary repairs after events such as storms or heavy rains. Community involvement and participation is usually critical for adoption of these conservation practices. In the modern sector the adoption of these techniques could become more difficult.

f. Crop Rotation

Crop rotation consists of growing different crops in succession on the same land, rather than utilizing a one-crop system or a haphazard change of crops. Under a rotation system, crops are alternated on the basis of the different amounts and types of organic matter that each crop returns to the soil. Rotations usually include one or more crops that require little or no tillage in order to counteract the effect of frequent tillage operations that accelerate the loss of organic matter. Deep-root penetration on the part of certain leguminous crops, such as alfalfa, provides better drainage as a result of the channels left after the roots decay.[113]

In Mexican agriculture, crop rotation is not a method readily used by most producers. Modern agriculture that emphasizes monoculture will further discourage crop rotation. Traditional corn producers normally use intercropping and other methods for growing associated crops with corn. But, as a general rule, rotation is not practiced. One technological restriction is the irregularity of the rain-fed cycle.

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[113] The rotation system employs special types of crops such as cover crops and green-manure crops. Cover crops are planted to protect soil; if leguminous plants are used, this also aids nitrogen fixation. Green-manure crops (*abonos verdes*) are grown solely to be plowed under and serve to increase the organic-matter content of the soil. An experiment in Veracruz (Luisa Paré and IDRC-CIMMYT project) shows that although no yield is expected of a green-manure crop, it helps increase yields of main crops planted in the same fields.

g. Integrated Pest Management

A technique that is available to counter any need for an increased use of agro-chemicals is Integrated Pest Management (IPM).[114] Integrated pest management involves the use of biological controls for pests such as predators, sterile insects and pheromone traps, as well as crop rotation. These techniques can be combined with the selective application of certain insecticides.

But IPM will not easily substitute for the chemical control of agricultural pests. The key indicator used to evaluate the performance of pesticide technology in the modern sector is yield, and IPM is still an immature technology and at a disadvantage compared with chemical pesticides.[115] Switching to IPM involves uncertainty, potentially lower yields, requires a high degree of coordination in order to reduce potential effects of the continued use of pesticides in neighboring fields and might require policy intervention. But as the State withdraws more from economic intervention on the part of the government is declining and technical assistance is increasingly being left to private entities (sometimes the same firms who produce and market chemical pesticides) through marketing and sales efforts.

h. Use of Hybrids and Improved Varieties

One technology associated with modernization is the use of hybrid and improved varieties of seeds for corn production. However, the penetration of hybrid seeds in the corn sector remains weak in comparison with other crops. This is partly due to the great variety of agro-ecosystems in which corn is produced in Mexico. Improved varieties and hybrids do not perform competitively in the conditions under which the majority of corn is produced in Mexico (Lothrop 1994). It is currently estimated that less than 25 percent of total harvested surface for corn is cultivated with the use of improved varieties and hybrids.

Data in Table 38 collected from individual companies indicate that in 1995 sales of hybrid seeds totaled 24,500 metric tons, down from 1991, reflecting the drop in Mexican GDP of 6 percent. CIMMYT analysts estimate the total area of hybrid maize production at 1.2 million hectares, using total sales and the average seeding rate of 21.3 kg per hectare. This indicates that hybrid maize varieties were used in 14 percent of the total surface devoted to maize production in 1995 (1.1 million hectares out of 8 million hectares). An additional million hectares may be under cultivation using improved open-pollinated varieties.[116]

Table 38 Total Sales of Hybrid Seeds

Year	Total Hybrid Seed Sales (metric tons)
1991	23,000
1992	27,000
1993	30,000
1994	26,000
1995	25,400
1996	19,800

Source: MacMillan and Aquino 1996.

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[114] Although many people believe that IPM is a recent innovation, this was the method of choice prior to World War II. In the post-war years, synthetic insecticides were introduced and they rapidly became the dominant pest control technology. Although there is evidence that IPM technology offers many advantages over use of pesticides, IPM appears to be favored only where pesticide use faces strong diminishing returns (Cowan and Gunby 1996, 525).

[115] A recent analysis in the context of "competing theories theory" (a theory of how competing theories come to dominate or be dominated), and in processes where inefficient technologies remain dominant, reveals that IPM is still an immature technology (Cowan and Gunby 1996).

[116] In addition, an unknown percentage of production comes from OPVs that are crosses with local landraces.

Table 39 estimates the potential for increased use of hybrid seed by geographic region. The first column shows data provided by individual seed companies for each state where hybrid seeds are used. The second column is based on work classifying Mexico's agricultural regions that seeks to identify the segment of corn producers which offers the potential for growth and increased competitiveness. Producers are classified in terms of regularity of hydric cycles and quality of soils (Turrent 1996). The technological package which Turrent considers viable for these producers includes the use of improved varieties (provided by *Productora Nacional de Semillas*). This information is analyzed in the context of soil erosion and data from Sagar on productivity and profitability of corn producers.

Table 39 Hybrid Seed Potential in Mexico's Agro-ecological Regions

Geographic Region	I Production with Hybrids *(thousands of ha)*	II Potential Medium Productivity *(ha)*
A. Subtropical Lowlands* (< 1000 masl) (Sinaloa, Tamaulipas, Sonora, Coahuila, Durango, Chihuahua, Nuevo León, small areas of Nayarit, Colima, Jalisco, Morelos)	630	
(Chihuahua and Tamaulipas)		155
B. Mid-Altitude (1000–1800 masl) (Jalisco)	250	590
(Guanajuato, Michoacán, Querétaro, Durango and Nayarit)	150	
(Guanajuato, Michoacán, Zacatecas)		522
C. Highlands (> 1800 masl) (Puebla, México, Hidalgo, Querétaro, Tlaxcala and Chihuahua)	20	
(México, Puebla, Oaxaca, Tlaxcala, Hidalgo)		839
D. Tropical Lowlands (<1000 masl, wet) (Veracruz, Chiapas, Tabasco, Campeche and Guerrero)	100	
(Guerrero, Chiapas, Yucatán, Veracruz and Quintana Roo)		777
Other		234
Total	1,150	3,117

* North of 23°, dry, most of production under irrigation, mostly in Autumn–Winter 1994–95.

Source: MacMillan and Aquino 1996 (CIMMYT).

Notes to data in Column II: Medium productivity of land is used as an indicator of potential for additional hybrid use. Medium productivity land is defined (Turrent 1996) as having: a) a total quotient of precipitation to evaporation from June to September between 0.5 and 0.9 with soils being more than 1 meter thick; b) a quotient between 0.7 and 2.0 with soils less than 1 meter thick.

2. Crop Substitution

For the 20 percent of the most profitable producers, reductions in the price of corn might encourage shifts from corn to more profitable crops such as horticulture. If and when this conversion takes place, the effect on corn production may be important because this 20 percent of producers is responsible for 50 percent of production and commands 28 percent of total irrigated land.[117] In order for this conversion to occur, existing distortions in relative prices must disappear.

The horticultural sector may pose considerable entry restrictions for many producers. A move to horticulture requires heavy capital investments, as well as established credit and marketing channels.[118] Thus, it will not be an option available to a large number of producers who will remain in corn production or move to alternative crops. Horticultural products in Mexico are currently grown on no more than 300,000 hectares compared to corn which is grown on 8.8 million hectares. A major effort to increase horticultural production could result in the dedication of an additional 400,000 hectares of rain-fed or irrigated land to horticulture.[119] This allocation could double its production. But the North American market will probably not be able to absorb more than that level of increase.

Recent trends in the export of horticultural products from Mexico to the United States indicate that the capacity of Mexican producers to displace US producers from the North American market has probably reached its limits.[120] In addition, an increase of harvested surface in horticultural products could affect their international price as these products, like other basic commodities, are vulnerable to price fluctuations and market saturation (de Janvry 1996).

Other issues would also have to be considered in a move towards non-traditional exports (Thrupp 1994). Strict marketing demands from the North American market need to be satisfied including stringent sanitary and phytosanitary standards; tolerance limits for chemical residues; high esthetic standards[121]; and strict compliance with delivery timetables of precise volumes (Thrupp 1994). These products have a short shelf life and thus require special production, packaging and handling technologies. These requirements tend to become more important as agro-biotechnology becomes dominant. Also, there is a need for well-developed marketing channels, transportation and infrastructure, both for inputs and for sales. In addition, horticultural production is heavily dependent on pesticides. Monoculture crops are common.

Shifting to horticulture involves a change in product and process technology. From an environmental perspective there are also costs that must be taken into account (see Thrupp 1994, 10–12). First and foremost is the heavy use of pesticides involved in horticultural production generally. The strict requirements from consumers for “blemish-free” produce contributes to the heavy use of pesticides.[122] Integrated pest management (IPM) is not yet a common practice among producers (see Cowan and Gunby 1996). Health hazards from the application of these pesticides can be severe. Second, producers may resort to the increased use of biotechnologies. The increased use of biotechnologies has the potential to affect the population of landraces and of wild relatives associated with engineered crops. There is also the potential for accumulation of residues from the increased use of agrochemicals that can affect water and soil quality. The issue of water quantity is also important as horticulture requires more water for production than does corn.

Finally, in horticulture there is a trend towards the use of cheap labor and unskilled workers. Most jobs created in this sector are temporary.

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[117] 1.7 million hectares in 1991.

[118] Technology adoption trends will increase this requirement, both in production and harvesting, as well as in post-harvest handling and storage. In addition, new trends in agro-biotechnology will contribute to increase capital requirements (Gómez and Schwentesius 1993; Thrupp 1995; de Janvry 1995).

[119] Horticultural production can be sustained under both systems as long as soils are well drained.

[120] Exporting to the European market is not an easy task and producers will encounter competition from growers in Chile, Argentina, Brazil, Ecuador, and Colombia. These countries are already penetrating the European and North American markets.

[121] There is already a risk of rejection due to non-compliance with cosmetic or esthetic standards (Suppan, personal communication).

[122] Pesticide inputs are particularly high in such crops as flowers, pineapples, mangoes and strawberries.

a. Substitution for Other Grains (Including Feed Grains)

The substitution of corn production by other crops (wheat, sorghum, oats, barley, soybeans) might occur. Indeed, the 1994 *ejido* survey reveals an important expansion of harvested surface in feed grains, as well as in the number of *ejidatarios* engaging in these activities (Gordillo et al. 1994). Such a substitution could result in the loss of landraces and of wild relatives of corn if it occurs in regions where landraces prevail. If this substitution takes place in regions where improved varieties and hybrids have been used over a long period of time, the displacement of landraces cannot be attributed to the more recent crop substitution. Erosion is less severe with crops which cover the ground evenly such as wheat than with crops grown in rows such as corn and tobacco. If more intense tillage and plowing is associated with a more intense mode of input-intensive production, and if this takes place on sloping lands, there may be an additional environmental stress on land. The same may be said for accumulation of residues of agrochemical inputs.

When crop substitution takes place, there may be a learning curve and post-harvest losses may be more important. This happened in 1994 when the irrigated systems of Mexico's northwest shifted to corn production (due to serious distortions in guaranteed and relative prices).

b. Land-Use Changes (Livestock and Tree Plantations)

Corn producers operating with losses and engaging in production for household consumption might remain in production of corn or may change their land use to livestock production or forestry projects. Most producers sell a significant proportion of their harvest in the local markets and thus will be affected by price reductions. They may also satisfy some of their own consumption needs with their production.

Changes in land use patterns in which land previously used for corn production is transformed into cattle production may be accompanied by a possible loss of landraces and wild relatives. There may also be effects on soil quality from compaction and overgrazing. In some cases marginal lands may be more readily converted to pasture without increasing pressure.

Recent legislation has effectively deregulated the forestry sector. Together with the reforms to Article 27 of the Constitution on property rights for *ejido*-owned land, the new legal regime may create opportunities for the rapid expansion of industrial plantation forestry through joint ventures in which *ejidatarios* provide land and investors provide capital, technology and marketing channels. In many cases, land that was devoted to corn production and later was used for cattle raising may be used for tree plantations.[123]

3. Continuing Corn Production Using Traditional Methods

A large number of corn producers will not be in a position to adopt new technology and will continue to produce using traditional methods. Under these circumstances, they will continue to engage in corn production, exerting additional pressure on their existing resources or "extensifying the use of technology" (de Janvry, Sadoulet, Davis and Gordillo 1995).

These producers do not have the capacity to convert their land to the production of alternative crops. They are subsistence farmers operating on marginal lands characterized by shallow soil with little drainage and frequently on sloping terrain. Typically, these producers have low yields.

Studies conducted at the household level suggest that these producers will be affected by reductions in the price of corn.[124] They will remain active in the corn sector producing for their own consumption. However, most will run a deficit in terms of their corn balance and will purchase part of the corn needed for their own household from other

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[123] Paré (1996) cites cases where producers have entered into these arrangements in La Chontalpa region (Tabasco).

[124] See for example, Garcia Barrios et al. 1991.

producers. In principle, they should benefit as consumers from the fall in corn prices. However, these reductions in tortilla prices have yet to become reality. But the cash needs of such small producers depends on employment opportunities in the local or regional labor market and the evolution of rural and urban wages. These producers may also satisfy their immediate cash needs through petty sales of grain in the local market (in these operations they probably confront a buyers' market in which they have very little bargaining power). The amount of time before they leave the corn-producing sector depends on the opportunity cost of reallocating their productive resources (land and labor) to other uses.

Data in Table 12 indicate that 64 percent of all producers operated with losses, and yet were responsible for approximately 29.5 percent of total production in 1991. It is possible that the survey overestimates the costs of production (especially labor costs). But these producers may continue to produce corn in order to avoid the high transaction costs involved in purchases at market prices. Thus, they may not benefit as consumers and will remain in operation under extremely vulnerable conditions.

Indeed, these producers are among the most vulnerable economic actors in the Mexican economy. They operate in states where Conasupo's activities are virtually nonexistent and rural poverty is high.[125] Taken together with technological stagnation, or even regression, the operations of these producers could have important environmental implications. (de Janvry, Sadoulet and Gordillo 1995; Gordillo et al. 1994).

Technological regression in the case of poor *ejidatarios* has manifested itself in a reduction in assets (such as animals) in recent years (Gordillo et al. 1995, Table 7.1). The percentage of producers who own oxen, mule and horses has decreased.[126] In addition, where migration is part of the economic response of these producers, technological regression can be intensified due to the loss of expertise in resource management.

Another indicator of vulnerability is provided by data from the *ejido* survey. Eighty-two percent of the sample of corn producers in that survey are involved in only one cycle, either the Spring–Summer cycle (74 percent) or the Autumn–Winter cycle (8 percent). Only 18 percent of *ejidatarios* who are maize producers in the survey sample grow corn in both cycles. This means that for the vast majority of producers (and their families) corn supply comes from only one crop during the year.[127]

These producers have to depend on their ability to purchase corn if they face a deficit during the rest of the year. They thus rely on monetary flows to satisfy household needs. Their need for cash arises from the need to purchase other staple foods, medicines, clothing, and tools. In addition, these households sell their labor in the local, regional, and national markets. Often they migrate to the United States to satisfy their income requirements. Provided they continue to find jobs and that real income grows, these producers will not be affected by the adjustment process. But employment creation is slow and real wages have fallen over the last eight years. In addition, price reductions in maize will continue to put downward pressure on real rural wages thereby affecting subsistence producers.[128]

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[125] Social indicators of the most recent nutrition survey in rural Mexico confirm this vulnerability (*Instituo Nacional de Nutricion* 1997).

[126] The 1994 *ejido* survey reports a decline in the technological conditions of *ejidos* (see Gordillo et al. 1995).

[127] Half of producers (47 percent) had small inventories of corn before the cycle started.

[128] Some consider this effect on real wages an advantage because of its positive effects on investment, growth and employment generation (see Levy and van Wijnbergen).

These production responses do not necessarily exist in isolation. Some are used by producers in combination.[129] In addition, production decisions may be prioritized differently in the two agricultural cycles. For example, in the Spring–Summer cycle, where rain-fed agriculture predominates, there may be a move towards household consumption, although this will not necessarily be the dominant strategy. In certain regions with very good rain-fed dynamics, modernization and crop substitution will be more important. In the Autumn–Winter cycle, the main production trend will be to modernize corn production, or to shift to other crops. Finally, some production responses have a dual effect on the micro level: implications for the land plot being cultivated, or for the water source being utilized. Taken together, however, their impact might be altogether different, not only from the quantitative point of view, but because the environmental impact may have a different nature.

C. Physical Infrastructure

The production of white corn in Mexico, in both traditional and modern sectors, requires a volume and variety of physical infrastructure, both public and private, beyond transportation networks and facilities for water, sewage and power. It requires, for example, extensive grids of terracing and storage and major irrigation networks. The maintenance of domestic production levels (despite the decline in domestic prices and increasing imports), combined with declining rates of public investment in basic infrastructure, has led to an infrastructure gap. These gaps are evident in arable land investments to prevent erosion, vegetative technologies, and irrigation infrastructure.

The importance of public investment in infrastructure is underlined in Levy and van Wijnbergen (1992), who conclude that efficiency gains may fail to materialize and spread to all social groups if adjustment measures such as investment in hydro-agricultural infrastructure are not adopted. García Barrios and García Barrios (1992, 262–3) show that production costs are increased by the lack of adequate investments in infrastructure. Until the 1980s the only available technology which could be used to arrest or prevent erosion was mechanical and required large capital outlays that could only be met by government. It is estimated that more than 90 percent of the arable land investments needed to combat erosion were deferred (Turrent 1997). This trend has been aggravated in recent years.

In the 1980s a new set of so-called vegetative technologies became available. Because these technologies do not involve large earthmoving operations and are affordable for private producers, some of these technologies can be used for integrated watershed management in water and soil conservation programs. Examples of these technologies include living wall terraces, vetiver grass, and alley cultivation. However, although costs are significantly below the old earth-moving technologies, the role of adopters is crucial. In many cases, the new technologies do not address limitations in the capacity of individual producers to make the necessary resources available.[130] For individual producers of maize in Mexico, a shortage of labor will continue to be an obstacle to the adoption of these technologies.[131]

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[129] An example is the combination of migration, cattle, and corn production identified in Gordillo et al. 1995.

[130] For example, vetiver grass *(Vetiveria zizanioides)* has been described positively in one World Bank report (cited by Sivamohan et al. 1993): vetiver increases sedimentation, reduces runoff and binds soils to a depth of up to three meters; its roots prevent rilling, gullying, and tunneling, while their aromatic nature makes the grass unpalatable to rodents and other pests. However, the inherent characteristics of these technologies are less important than their integration into local farming practices. For example, Sivamohan et al. (1993) report that in the case of vetiver grass, whether its root system is invariably three meters deep or not is less important than whether farmers adopt vetiver as part of their own strategies. Vetiver grass was particularly popular in ex-colonial cash crop plantation agriculture (sugar, rubber, tea, coffee, and fruit). In these production systems, heavy maintenance was possible because of the large amounts of labor they require.

[131] "The expenditure of scarce resources required for the management of soil and water conservation systems are often not made by farmers with small land holdings because they are forced to focus on short term rather than long term benefits." (Sivamohan et al. 1993, 297).

In addition, most vegetative technologies for soil conservation require significant capital outlays and labor inputs. Their adoption may be discouraged in favor of short-term profit maximization and unit cost reductions. Because the long-term effects of erosion (which may be felt in time horizons of up to 60 years) are not factored into the cost, growers tend to disregard them and market signals are not apparent until it is too late. Fertilizers may be heavily relied upon until land fertility is almost entirely substituted by agrochemical inputs, and erosion will eventually occur.

Irrigation Infrastructure

A critical element for agricultural development is the construction, operation and maintenance of hydro-agricultural infrastructure. Indeed, Levy and van Wijnbergen (1992) conclude that efficiency gains may fail to materialize and filter to all social groups if adjustment measures such as investment in hydro-agricultural infrastructure are not adopted during the transition period established by NAFTA for corn.

Data in Table 40 indicate that federal investment in new irrigation projects has been decreasing for both large and small irrigation projects. In real terms, the level of investment for 1994 has not recovered, except in the case of small irrigation projects. Although small irrigation projects are necessary,[132] the data show that the surface newly converted to irrigated cultivation has declined since 1988. New surface brought under irrigation has declined steadily since 1991. In 1996 the total number of hectares of new land under irrigation is one-sixth of what it was in 1991. Thus, the rate of growth is declining.

Those projects that do emerge tend to be small. A move away from the larger projects that have tended to dominate infrastructure development in the past might be useful if the smaller project can show increasing returns on investment and affect a range of producers.

Table 40 Investment in Hydro-Agricultural Infrastructure, 1988–1997

	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
New Investments					*(Millions of 1993 pesos)*					
Total	438	643	884	1018	1043	560	520	241	268	287
Large Irrigation	200	272	359	339	360	148	153	53	66	56
Small Irrigation	85	144	215	261	203	77	65	29	40	67
Rehabilitation	125	110	226	360	395	256	213	131	98	74
Protection[1]	28	117	84	58	85	79	89	28	64	90
O&M[2]	4	23	22	21	40	32	30	33	46	38
Irrigated Land					*(Thousands of hectares)*					
New Irrigated Land	28	21	38	39	32	13	11	5	10	6
Large Projects	4	6	20	32	27	11	8	3	7	5
Small Projects	24	15	18	7	5	2	3	2	3	1
Rehabilitated and Improved	3	35	44	164	176	100	116	64	38	32

[1] Protection of productive and urban areas.
[2] O&M: Operational and maintenance costs.

Source: Prepared with data from Ernesto Zedillo, Anexo del tercer informe de gobierno *1997.*

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[132] Particularly in the mountainous states of Guerrero and Oaxaca, where small river basins and watersheds still offer good irrigation potential.

D. Social Organization

Issues related to social organization are important for the changes unfolding in the maize sector. Key issues include social institutions and the closely-related property rights regime, subsistence production and the availability of a labor force, and migration. In many cases, while production has been maintained in spite of price reductions, those reductions have led to social changes that could affect the environment. Most generally, the social and cultural importance of corn is particularly relevant to the conservation of genetic variability and soil. In many corn-producing regions of Mexico, indigenous peoples have maintained a long-standing system of sustainable production through complex resource management schemes incorporating sophisticated knowledge of soil properties and the genetic characteristics of different corn varieties.

1. Social Institutions and Property Rights

Social institutions provide the main support for the use and development of many production techniques.[133] Weak institutions of social governance could lead to the deterioration or abandonment of otherwise feasible technologies and techniques because traditional techniques of land cultivation usually depend on a large pool of labor (see García Barrios and García Barrios 1990). Poverty and pressures to migrate in search of economic opportunities could weaken the social fabric that supports corn production. Thus community organizations may be faced with the challenge of structural labor shortages that could undermine their capacity to carry out the necessary tasks for sustainable corn production.

Collective resource management is common in many communities in rural Mexico. Although frequently associated with collective ownership of land, forests and water, the *ejido* regime is not a common property resource management scheme. In a typical *ejido*, individual plots are owned and exploited by a single producer, while the community is the owner and administrator of communal graze land, forests or water sources.

The delicate institutional fabric through which the community manages these resources is a critical foundation for sustainable production. Adequate patterns of resource use surrounding the routing of herds, time of grazing, seasonal use of land, and access to forest and water resources, are all identified, approved and enforced by the different governance bodies in the community. If these institutions of social governance are weakened, collective work is threatened and efficiency diminished.[134] Over-grazing is a typical result, as is a lack of coordination in harvest dates that can disturb resource allocation. Overgrazing can accelerate loss of topsoil and risks of erosion. It also leads to the inability to carry out adequate maintenance of physical infrastructure (such as terraces or irrigation systems) when the corresponding tasks are labor-intensive and/or cooperative labor is required.

Shifts in production away from corn and into labor-intensive commodities such as fruits and vegetables could reduce the corn-producing population and erode the traditional social and community institutions responsible for resource management in many areas of Mexico.

2. Subsistence Producers and Rural Employment

Subsistence production is concentrated in southern and southeastern Mexico, as well as in the states of Mexico, Puebla, Tlaxcala and Hidalgo in central Mexico. As Figure 11 shows, these states also concentrate low-income producers. These producers operate small plots, using local landraces. Some literature on NAFTA assumes that price reductions will benefit those producers who show a deficit in their corn accounts and that a high proportion of Mexican producers will not

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[133] See Collier (1992) on Zinacantán in the state of Chiapas.

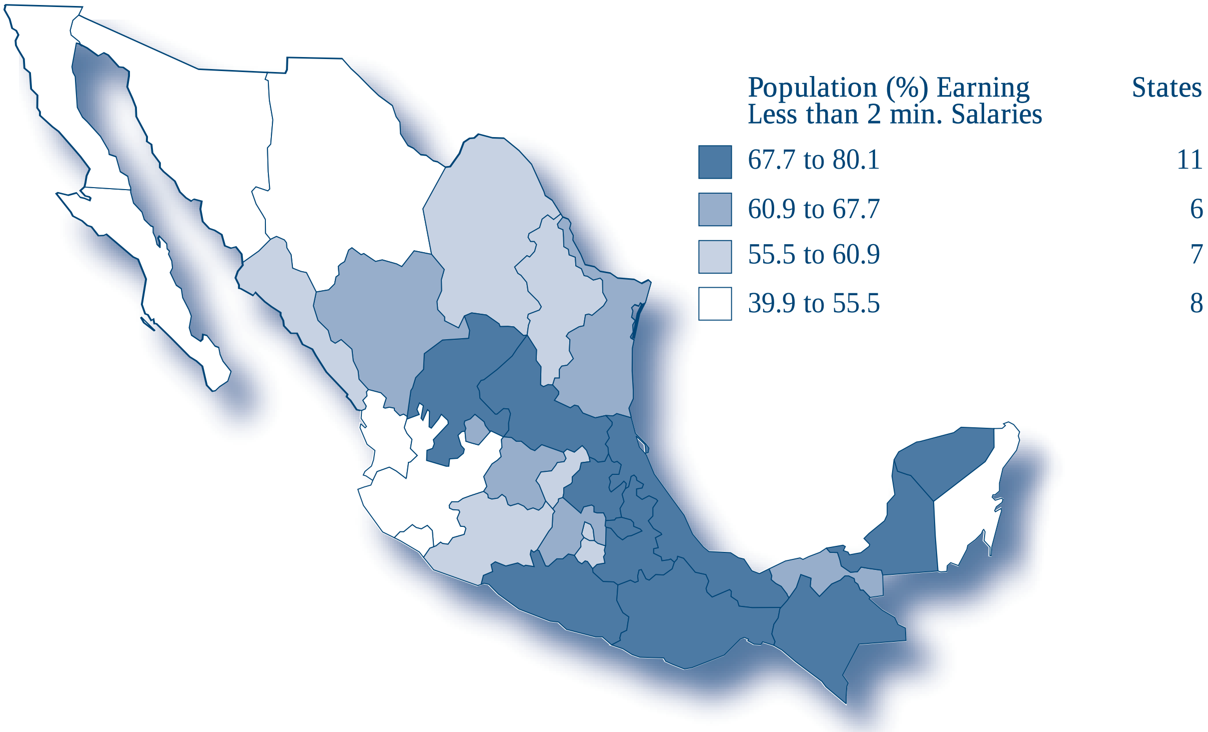
[134] A case study in many communities in Michoacán (Argueta, Gallart et al. 1992) shows how the weakening of these institutions leads to inefficient resource management in communities in which sustainable production had been the norm.

be affected by price reductions because they produce only for household consumption (Masera 1990; García Barrios 1991; de Janvry et al. 1995; Levy and Wijnbergen 1992). Many analyses based on the results of the 1994 *ejido* survey show that close to 60 percent of *ejidatarios* (responsible for 38 percent of total corn production) do not sell their corn in the market and use it exclusively for household consumption.[135]

However, subsistence producers are not always self-sufficient. A typical household will harvest and store grain to use during the calendar year. Normally, small amounts of the crop will be channeled to the marketplace to meet income needs arising from debt or the need to purchase other goods and services and meet normal household expenditures.[136] Indeed, many traditional subsistence producers of maize use modern purchased inputs (fertilizers and pesticides) in their production.[137] Sources of income vary from cash receipts from household members who sell their labor in the local labor markets, remittances from household members who migrate, or income earned through other activities such as production of cloth, embroidery, baskets or hats. The view that subsistence farmers will not be affected by price reductions for corn ignores the fact that these producers rely on monetary flows and depend upon income from off-farm activities.

Consumer prices for tortilla, dough *(masa)*, hominized grain *(nixtamal)* and raw grain have not dropped. One reason is that intermediation and market segmentation have maintained price rigidities in localities. Several corn producers are faced with selling corn into a buyers' market and purchasing tortillas in a sellers' market. Thus, subsistence producers whose corn accounts show a deficit face high transaction costs when they have to purchase corn in the market (de Janvry 1995; Levy and van Wijnbergen 1995; García Barrios et al. 1991).

Figure 11 Low Income Population



Source: Calculations based on data from INEGI, XIth Population Census.

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[135] See de Janvry 1996 and de Janvry et al. 1995.

[136] This study excludes nonsellers of maize who own livestock and need the grain they produce for animal consumption as well as nonsellers with diversified cropping patterns in which maize production is a marginal activity (see de Janvry et al. 1995).

[137] See Gordillo et al. 1994.

The seasonal nature of agricultural labor makes it difficult to estimate the number of workers engaged in agricultural activities. Income derived from agricultural activity is generally not enough to sustain a family for a year. Thus, there is often the need to work in other farmers' plots or to migrate temporarily to towns and cities.

Price reductions of corn will affect real rural wages and subsistence corn producers who need to generate income. The 1994 *ejido* survey confirms that off-farm employment is the most important source of income for these producers. Thus, if corn-producing units are displaced from the corn market, the employment opportunities for these subsistence farmers will disappear because the corn producers who employ them will be affected by increased competition.

Even if the drop in corn prices does not affect subsistence producers, their sources of employment may be affected because they are employed directly by more competitive corn producers who sell into the market. If these producers opt to abandon corn production, rural migration flows could increase because the resulting lack of income will induce a greater number of small and medium-sized producers to search for job opportunities outside of their towns and villages (Salas 1997).

Thus, the idea of open unemployment does not provide an accurate understanding of the characteristics of labor in rural areas. In times of low agricultural activity, those people not currently working do not look for work in the areas where they live. They already know there are no jobs available. So the standard conditions to be considered in open unemployment—lack of work and active job search—are not fulfilled. Data on rural unemployment come from the National Employment Survey and show that unemployment rates in rural areas are nil for all practical purposes and less than 1 percent of the labor force in less urban areas.[138] Recent estimates of rural employment put the total figure at around 7,000,000.[139] National Employment Surveys (ENE) were conducted in 1988, 1991, 1993, 1995 and 1996. These surveys gather data for the second quarter (April-June) of the year. Table 41 compares data from 1991 and 1995 indicating an apparent reduction in the labor force employed in agricultural activities.

Table 41 Agricultural Employment, 1991 and 1995

	1991	1995
Producers	4,312,790	3,123,189
Direct Workers	4,541,336	4,150,609

Source: INEGI, National Employment Survey, 1991 and 1995.

The drop in the numbers of producers (including private owners and *ejidatarios*) and direct workers is due to a change in methodology and cannot be attributed to land purchases after the legal reform to Article 27 of the Constitution. It is possible that some of the impact of these legal changes can be captured in the data in Table 42 from 1995 and 1996 because the two years are comparable.

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[138] In the National Employment Survey, less urban areas are cities and towns with less than 100,000 inhabitants.

[139] Author's calculation based on *Instituto Nacional de Estadística, Geografía e Informática* (INEGI), *Encuesta del conteo de población 1995*, Aguascalientes 1997.

Table 42 Agricultural Employment, 1995 and 1996

	1995	1996
Producers	3,123,189	2,769,391
Direct Workers	4,150,609	3,885,571

Source: INEGI, National Employment Survey, 1995 and 1996.

Displaced workers from the corn sector could be absorbed by employment in other sectors such as horticulture and other more labor-intensive crops. Preliminary indicators taking into account size of markets, dedicated surface for different crops, evolving technologies, prospects of international competition, and availability of inputs reveal that such absorptive capacity might not exist. Mexico already accounts for 70 percent of the seasonal (winter) US horticultural market.

In addition, tariff-free corn imports have been diverted in significant amounts to producers of high fructose. According to some reports, in 1996 between .3 and 1.2 million metric tons of imported corn were directed to the manufacture of high fructose by a few plants in Mexico. Fructose is being used as a sweetener and affects local sugar producers. If the trend to substitute sugar with fructose gains momentum, the impact on the sugar industry could be significant.[140]

3. Migration

Migratory flows are an important component of households' economic strategies. For corn-producing households to satisfy the need for additional income, selling part of their labor in the local labor market is a critical source of revenue. But migration is not only related to income generation; it affects the technological options open to the household in terms of input and output mix, and it affects land use patterns and has important implications for the conservation of genetic resources.

Migration is a resource allocation response at the household level to changing economic realities. It modifies the availability of land, labor and money to the individual household. Remittances are an important resource for the household, and there is evidence that they constitute a crucial form of support for Mexico's corn producers. The migratory process that underlies these remittances can result in labor shortages at the household and community levels. A study at the community and household level in a locality relying on corn production (García Barrios and García Barrios 1990) suggests that this generates new sources of risk, insecurity, and an inability to maintain adequate resource management capabilities.

Excessive emigration means that absolute population numbers and household sizes decrease. This has important consequences for the availability of labor for agricultural practices. The money supply at the local level expands, and both production and consumption processes become increasingly dependent on monetary flows. In addition, land is abandoned and land managed per household increases because of land lending and sharecropping.[141] Taken together, these phenomena stretch the capacity of a household to monitor production processes and therefore its capacity to maintain all of the agricultural practices which are required for sustainable agriculture in its own agro-ecological environment. It is therefore important to analyze in detail the potential for further migration from corn-producing areas as the NAFTA regime unfolds and domestic corn prices converge on international prices.

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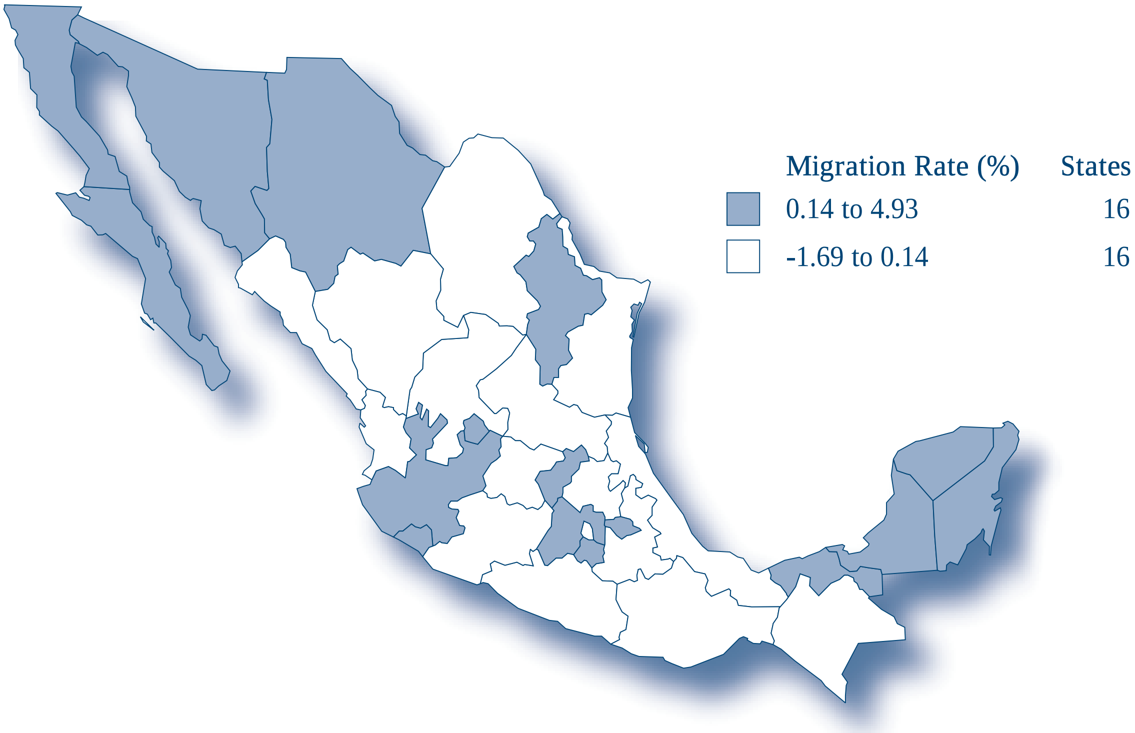
[140] It has been estimated that in the medium term, fructose (which costs as much as 30 percent less than sugar) may absorb more than one third of the sweetener market in Mexico, displacing local sugar producers: as many as 20 mills processing the raw produce of more than 200,000 hectares may be threatened. The number of affected jobs, considering cane cutters and other workers may be up to 150,000. Direct communication, Víctor Suárez Carrera (Executive Director, ANEC).

[141] This is also supported by evidence in the 1994 ejido survey (Gordillo et al. 1994).

There is a lack of systematic good quality data on recent migration patterns from rural areas of Mexico.[142] Indirect methods must be used to evaluate the potential for migration of poor rural populations. By their nature, these methods do not allow for extremely accurate results, but they do provide estimates of potential trends. Figure 12 illustrates general patterns of migration in Mexico.

Figure 12 Migration rate



Source: Salas, special report 1997.

Migration patterns by state between 1990 and 1995 are illustrated in Figure 13.

As a contribution to this study, Salas (1997) evaluated potential migration of labor in corn-producing areas in Mexico to identify those states with the greatest potential for migration. His analysis is based on specific clusters of states as illustrated in Figure 14. A complete discussion of this study is attached as Appendix B.

Chiapas, Guerrero, Hidalgo, Michoacán, Oaxaca, Puebla, Querétaro, Quintana Roo, San Luis Potosí, and Tlaxcala represent a group of less developed states and are considered together as “Cluster 1” (as illustrated in Figure 14). Common to these states are their high level of poverty, (indicated by a large share of the labor force with low income levels), a high proportion of corn-producing units with technologies which are not capital intensive (considering hybrid use as an indicator), and high rates of corn production for household consumption.

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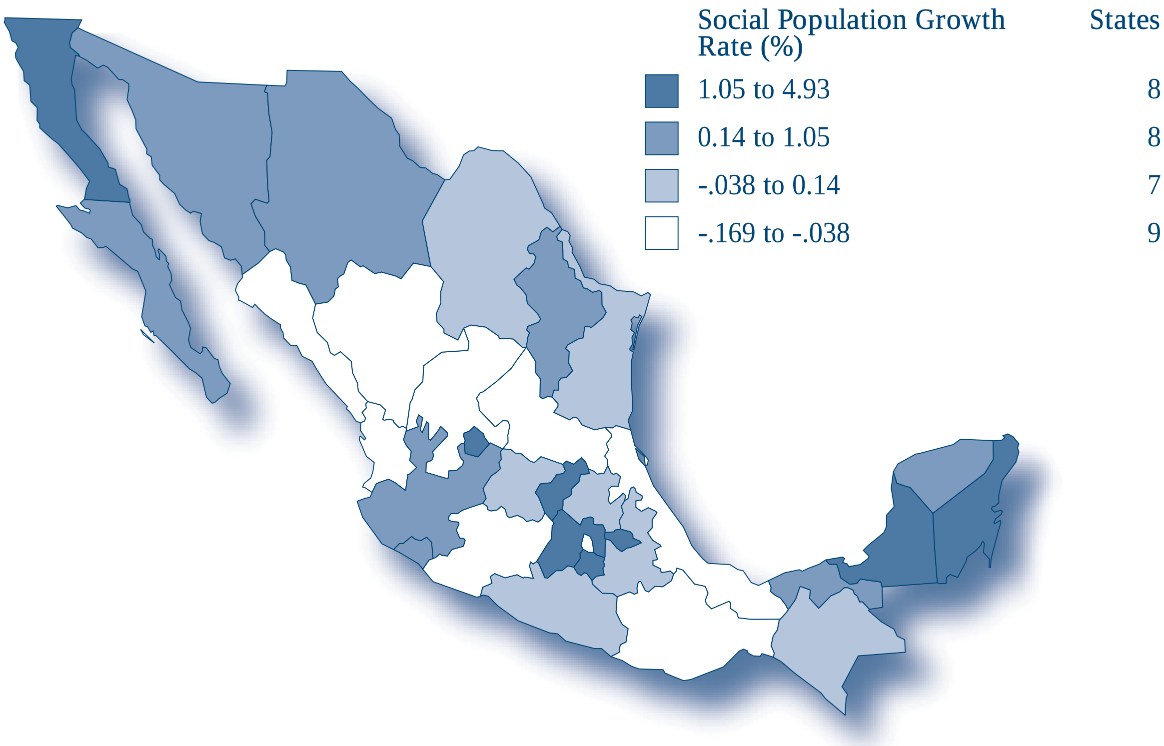
[142] A good discussion of Mexico-United States migration estimates can be found in Corona and Tuirán (1997).

Figure 13 Migration by State 1990-1995



Source: Calculations based on data from INEGI, XIth Population Census.

At the state level, Chiapas, Querétaro, Quintana Roo and Tlaxcala are generating the highest numbers of permanent migrants. A disaggregated analysis at the municipal level shows that most municipalities are experiencing emigration. This indicates a close link between levels of development and permanent migration. Lower income levels and traditional corn producing techniques are associated with higher levels of migration.

There is a relationship between economic and social underdevelopment and a propensity for permanent emigration. The fact that states with a large number of subsistence agricultural units are also poor suggests that "Cluster 1" states will experience the greatest impact from emigration by corn producers. This is a consequence of the fact that units using most of the product for consumption in the household are corn and bean producers.

There is a lack of data on temporary migration. An approximation can be found in data on migrant agricultural labor released by Sedesol in 1997. The results of these surveys show that the states of "Cluster 1" are where much of the temporary labor force comes from. The surveys also show that among the main reasons why temporary migrants *(jornaleros)* migrate are lack of land and lack of income.

Figure 14 Clusters for Migration Analysis

Source: Salas, special report 1997.

The analysis suggests that areas from which the agricultural workers emigrate tend to be predominantly peasant economies, with small production units, shallow or eroded soils, and little diversification of production. Thus, states that are important sources of agricultural labor force migration are Oaxaca and Guerrero. States that attract migrant labor are Baja California, Baja California Sur, Sonora, Sinaloa, Tamaulipas, Morelos, Nuevo León and areas of Coahuila and Durango. A third group of states experiencing both immigration and emigration includes Colima, Chihuahua, Jalisco, San Luis Potosí, Chiapas, Durango, Guanajuato, Hidalgo, Michoacán, Puebla, Tabasco and Veracruz.

This implies a greater potential for migration in those states where low-income levels are combined with a larger proportion of small plots, and low production technology levels. Existing trends may well reinforce significant migration from traditional producing areas as mid-sized farmers leave the corn market as a result of falling prices and competition between domestic and imported corn, resulting in fewer employment opportunities. For small producers whose households rely on local job opportunities this will generate additional pressure to migrate to more distant labor markets.

Significant migration does not occur among the poorest producers because of the associated costs. Social networks are important in the gradual establishment of migratory patterns as they reduce migration costs and eventually may operate under conditions of increasing returns to scale.[143] In a reciprocal situation, where social institutions and (blood and ritual) kinship relations provide means to mitigate the effects of economic penury, migration may be less of an incentive. If economic pressures such as inadequate farming and off-farm incomes and lack of local employment opportunities weaken local institutions and relationships, migration may increase.

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[143] On the importance of these social networks see Natural Heritage Institute (1997).

Table 43 indicates the age distribution of the agricultural population by property rights regime. It shows that the mean age group of agriculture's labor force is high in comparison with the urban labor force. This data also confirms outward migration from agriculture towards other activities and the inability to replace the elderly labor force remaining in corn production. This will result in the loss to Mexican agriculture of technical information regarding soils, seeds and agro-ecosystems that may have serious environmental consequences.

Table 43 Age Distribution of Agricultural Population, 1995

Age Group	Proprietors (%)	*Ejidatarios** (%)
12–24	4.36	5.49
25–44	37.07	36.83
45 and older	58.57	57.67

*Includes *comuneros*.

Source: INEGI-STPS, 1996.

Some analyses of NAFTA have cited important migratory flows as a consequence of the restructuring in agriculture on corn producers.[144] A comparison of data from two ejido surveys between 1990 and 1994 reveals that the average size of families in the sample decreased as a result of migration (Gordillo et al. 1994, 3.1). The same comparison showed that migration occurs most frequently among individuals between 30 and 45 years old. The migratory deficit in 1994 is stronger for the 20- to 30-year age group with a 21 percent deficit for individuals between the ages of 20 and 25. Fifty-four percent of migrants traveled to the United States. For households with plots of land between 5 and 10 hectares the number was even higher—64 percent.

Migratory flows partake of a complex relationship with the environment. On one hand, environmental degradation may be a force that drives migration, while on the other, migration may cause environmental deterioration. A self-reinforcing pattern may thus be established. In another study by de Janvry et al. (1997), poverty is positively correlated with environmental stress (which is measured through forest degradation and proxy variables for soil quality). But increased poverty makes it more difficult to overcome the high risks and transaction costs involved in decisions to migrate.

When migration occurs, the demographic structure of the affected communities changes rapidly. First, the labor force is reduced. This can impact resource management (including soil management and seed recognition, conservation and use). Social institutions that support labor-intensive production practices through cooperative arrangements can also disappear due in part to the shortage of labor and/or substitution by waged labor. (García Barrios and García Barrios 1990).[145] A key technological decision in production is related to the generation and selection of seeds. As migration occurs and landless laborers rent plots or enter into sharecropping arrangements, decision-making over which seeds

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[144] Calva (1991) predicted major population displacements. Levy and van Wijnbergen (1992) estimated the number of people displaced from the corn sector at 419,000, using a partial equilibrium model, and put the figure at 700,000, using an intertemporal model (1995). In several studies, de Janvry et al. have consistently considered these estimates to be exaggerated; they base this assertion on the alleged large percentage of corn-producing *ejido* households which are nonsellers and that, therefore, may be unaffected by price changes. De Janvry et al. (1995) notes that previous studies overestimated the displacement effect because they systematically ignored the possibility of using an array of policy instruments to help maize producers diversify, but they find a disturbing institutional vacuum in terms of lack of adequate credit sources and technical assistance. In addition, international migration (to the United States) will be affected, given the slow employment generation capacity of the Mexican economy (Tuirán 1997).

[145] The recent experience in Mexico has been that off-farm complementary sources of income are not necessarily the answer to better resource management for corn producers. When migration reduces the family supply of labor, and corn production is maintained, hired workers are needed. But the use of waged labor reduces control over key production decisions by the more experienced producers. The impersonal bonds implicit in waged labor relations make it more difficult for these experienced producers to maintain adequate supervision over key production decisions (García Barrios et al. 1991, 175).

should be used is retained by the landowners. However, the loss of control over the entire productive process is frequently accompanied by a deterioration of the relation between seed selection and other aspects of cultivation.

Migration may relieve pressure on marginal lands and allow for longer fallowing periods, in which case essential soil properties may be restored. However, it is also possible that pressure on land, even on marginal land, may persist as migration takes place.[146] Producers in some areas might rely more on small animals such as sheep and goats as an economic alternative.[147]

Where sloping land is left fallow but is used for pasture by small animals (goats and sheep) without adequate supervision, soil conservation becomes more difficult. This is exacerbated when migration takes place. Typically, in these cases children are sent to look after herds. Grazing is intensified regularly in the afternoon hours when children leave school. Inadequate practices may encourage overgrazing, eliminating cover and assisting erosive processes. This is the case of land in the municipality of Yanhuitlán in Oaxaca (Contreras Hinojosa 1996).[148] Where terraces are abandoned, the labor force required to repair damage after severe storms will be missing and erosion may set in.

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[146] Evidence from a study in 1985 in San Andrés Lagunas, a community in the Mixteca, shows that migration caused scarcity of labor at the same time it released land from production. But production on land under a lease contract increased (by 1985, 43 percent of total corn production in the community was coming from land under a lease contract). Similar events may indicate that pressure on land may continue even as migration occurs. In these cases, the combined effect of continued production and less trained labor may further disturb resource management capabilities. (García Barrios et al. 1991)

[147] Official policy through PROGRESA (the new administrations anti-poverty program) relies on small credits for the purchase of goats and sheep. These loans are targeted towards the poorest *ejidatarios*. One effect of tending these animals is that pressure on soil is greater and that erosion may occur at a faster rate.

[148] The same study indicates this conclusion may be extended to cover much of the Mixteca region in Oaxaca.

V. Environmental Impacts and Indicators

The environmental impacts of changes in production, government policy, social behavior and infrastructure will be felt in a sequence of events as the economic forces released by trade and investment liberalization unfold.

In some cases, continuing corn production using traditional methods will result in increased pressure on land and water. As erosion increases, or as soil fertility diminishes, producers are caught in a process where reduced yields of corn impose greater pressure to minimize costs. This pressure is relieved through cuts in operations necessary to maintain long-term productivity and fundamental soil properties. Loss of genetic diversity may be slowed as these producers rely on a large variety of landraces as part of their production strategy. But their ability to conserve different varieties of corn could be negatively affected by migration (which intensifies in response to a greater need to obtain income from off-farm activities as corn prices decrease). Because so much of Mexican maize is produced by households, often outside the wage-market economy, the dynamics of social organization will have a critical impact on how production decisions impact the environment, particularly in regard to genetic diversity and soil quality.

The environmental impacts of changes in production will depend upon the number of competitive producers in the modern corn-producing sector and the number of subsistence producers who remain in this sector. To an important degree, environmental effects will depend on the technical changes introduced by the first group and by the degree of technological deterioration experienced by the second.

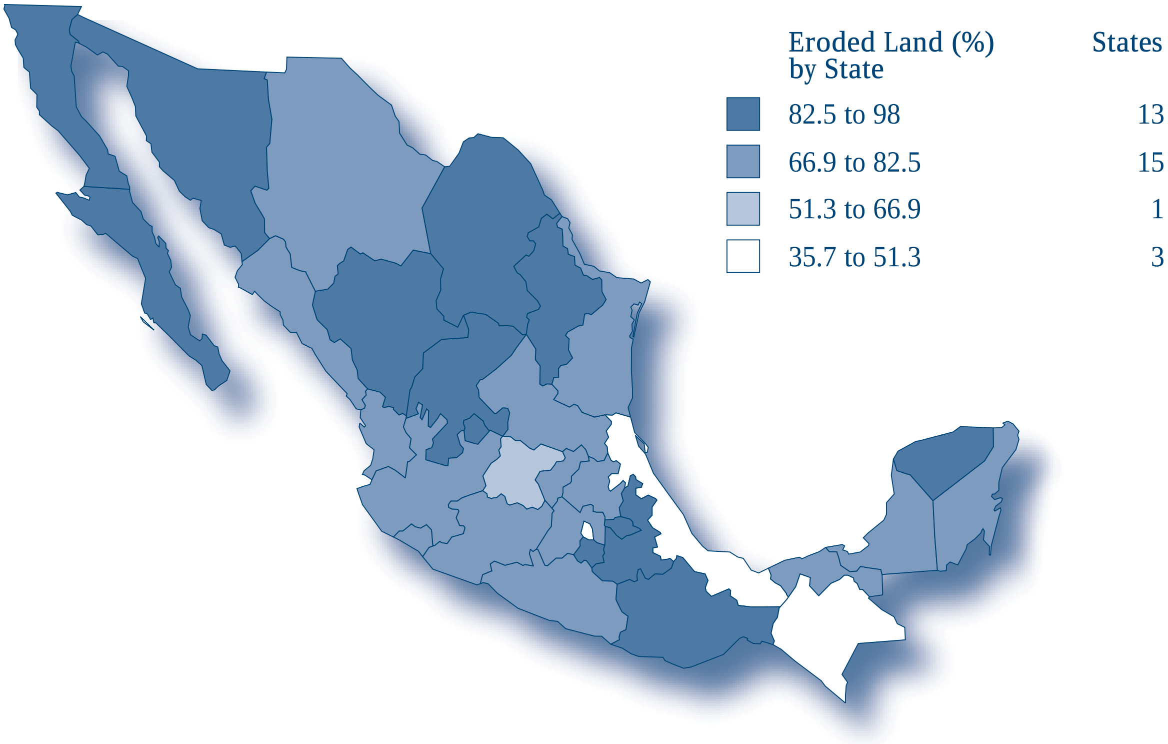
This section identifies where those processes are most likely to have environmental impacts on land, water, air and biota. It further suggests indicators that would be useful in order to monitor environmental change.

A. Land: Soil Quality and Quantity

Loss of topsoil, different degrees and types of erosion, reduction in soil fertility, salinization and accumulation of diverse agrochemical residues are important issues related to land. Both hydric and eolian erosion affect a significant proportion of arable land in Mexico. Soil erosion caused or aggravated by rainfall already affects 67 percent of Mexico's agricultural surface (Turrent 1997). One reason for this is that much of Mexico's agriculture takes place under conventional tilling practices (which are not designed to prevent or arrest erosion) on land with slopes equal to or greater than 4 percent.

Figure 15 indicates that erosion in Mexico has been most pronounced in the southern tropical regions of the country. These regions also have more intense precipitation and greater frequency of steeper slopes than the semi-arid northern regions. However, despite less precipitation in the north, vegetative cover is also less dense and the epipedon is shallow. Irregular rain patterns and erosion reduce productivity, further reduce the thickness of the epipedon and make land vulnerable to drought (Turrent 1997).

Figure 15 Land Erosion



Source: Environmental Statistics, INEGI, 1994 data.

Erosion results in the loss of soil fertility and a decrease in productivity when the epipedon[149] is truncated. Although this process may be temporarily retarded (if there is enough rainfall or through the intensive use of fertilizers) and agricultural production may continue, profitability will decrease. Some farmers may find themselves employing unsustainable practices or putting additional pressure on their land (or common property) to offset lower yields.

There is no systematic, reliable measurement of erosion rates and loss of topsoil in Mexico. The difficulties in obtaining adequate measurements and of extrapolating to local and regional levels may be at the root of this lack of adequate information.[150] The most important obstacle is the nature of the different processes of erosion. Sheet, rill, and gully erosion can take place in localities close to each other and their coexistence in small communities makes generalization very difficult. An indicator could be developed to monitor this.

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[149] Including parts of the B horizon.

[150] For a detailed explanation of measurement and associated technical difficulties see Pimentel (1993), Rickson (1994), James (1994), and Blaikie (1985).

NAFTA-induced production processes are not the primary cause of erosion. In some instances and regions, however, the production techniques that respond to the economic forces unleashed by NAFTA in the agricultural sector in general and the corn sector in particular could accelerate existing trends.

The possible environmental effects on soil of the modernization of corn production and use of modern technology and changes in land use such as the introduction of monoculture are extensive. The arable land which is of reasonably good quality and whose use could be changed is estimated to be between 16 and 18 million hectares. Approximately half of this land is sloping terrain. If changes in land use occur on a significant scale in the half that occupies sloping terrain, there might be increased erosion (Turrent 1997). Tree crop plantations or industrial forestry plantations can be part of this process. Environmental stresses may arise if biota is affected negatively or if soil quality and water availability are disturbed. If plantations are introduced on marginal lands in which corn production was taking place, however, soil quality might improve.

There are also several agricultural practices aimed at improved conservation of soil.[151] One of the most important methods to control or retard erosion is to maintain good vegetative cover. Plant cover intercepts and dissipates the energy of raindrops before they strike the soil, minimizing saltation effects and reducing damage. In addition, plants' roots and stems diminish runoff and facilitate filtration of water. Soil humidity increases and further facilitates plant growth in a self-reinforcing process.

Other methods include contour planting, terracing, live or green walls, cover crops, mulching, crop rotation, fallowing, no till or minimum tillage, ridge planting, and alley cropping. Some of these practices have existed for decades but have not been in general use. In other cases, such as terracing, either heavy earth-moving equipment is needed or very large supplies of (usually community) labor are required as part of the initial investment. Labor is also required for the maintenance of these structures. Recent work on cover crops in the Sierra de Santa Marta, State of Veracruz, indicates good potential to increase returns to poor producers and reduce environmental stress (Buckles and Erenstein 1996). Vegetative technologies need less labor input or heavy capital equipment but demand significant maintenance.

Tillage practices vary greatly in Mexico. Mechanized plowing is performed in areas where terrain surface and slopes permit. But capital costs associated with agricultural machinery are very high. Tillage is performed using animal traction, a method that offers greater versatility on steep terrain. More labor-intensive systems for tillage are also used in many regions. Plowing and tillage prepare soil for growing crops by turning the soil, removing weeds, and loosening and breaking up the surface layers of the soil. Cultivation with the system of row crops permits further weeding. Traditional tillage may harm the soil if used continuously over many years, especially if the fertile topsoil layer is thin.

Data on the use of pesticides in Mexico is sparse and data that focuses on the use of pesticides in the context of corn is difficult to obtain.[152] It is clear that the use of fertilizers has dropped in the last two years due to the increase in their price. Fertilizers and other agricultural chemicals applied to soils as inputs, together with industrial and domestic waste-disposal practices will increase soil pollution. Persistent toxic compounds, chemicals, and salts, which have a deleterious effect on plant and animal health, have built up to dangerous levels in soils. In addition, agrochemical residues also accumulate at different rates in different soil classes, and irrigation of arid lands often leads to accumulation of salts.

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[151] See Villar Sánchez 1996.

[152] For the purposes of this study, Alatorre (1997) compiled data from the Health Ministry *(Secretaría de Salud)* on cases of intoxications by pesticides in Mexico, by state and for a series of years. The data is organized and presented by week and year in which the case was reported and in some cases will allow for the identification of a targeted crop and a specific pesticide.

Industrial wastes pollute soils and arsenic compounds accumulate in soils following years of spraying crops with lead arsenate. The application of pesticides has also led to short-term soil pollution. An indicator for the use of agrochemicals per hectare of a specific crop could be designed. And combining this with information on cultivated surface could provide an estimated level of agro-chemical use.

Little is known about the management of soil acidity. This is important because adaptation of various crops and native vegetation to different soils depends on the ability to control acidity (for example, strawberries can be successfully grown only in moderately acid soils, whereas alfalfa and other legumes are successful only in weakly acid or slightly alkaline soils). The ordinary procedure for correcting excess soil acidity is the application of lime in the form of limestone, dolomitic limestone, or burnt lime. When lime is added to soil, the hydrogen of the complex soil colloid is exchanged for the calcium of lime. Acid soils are found predominantly in regions of high rainfall; in arid regions, the soil is usually alkaline. In the case of Mexico, some of these issues must be taken into consideration as crop substitution takes place.

If production induced by NAFTA leads to significant changes in land use, richer lands could be subject to pressure from commercial agriculture. Pressure to reduce unit costs means that long-term effects on land (such as the half-life of the epipedon) are secondary considerations in production decisions.

In the traditional sector, economic pressure may force producers to keep land under production under difficult conditions. This could prevent communities from taking appropriate action to arrest soil degradation and adopt measures to prevent erosion. In this context it is important to recall the fragility of soils and the economic and social costs that accompany widespread deterioration of soils. Ecological disruption of soils can take place very quickly.[153] In addition, evidence points to more intensive use of marginal lands under conditions that may imply greater geomorphologic risks. These trends contrast the traditional and modern sectors of corn production, lands in slopes and plains, as well as the semi-arid region in the north and the tropical region in the south.

Social behavior such as migration can affect erosion particularly in areas where labor-intensive maintenance is required for techniques to prevent or mitigate it. In areas where terraces have been built, maintenance is required to preserve those structures. This is particularly important during the rainy season when heavy rains can damage terraces. If the damage is not repaired immediately, additional terraces downstream can be destroyed. Over time, this can lead to the destruction of an entire system of terraces and thus accelerate erosion (Cerda-Bolinches 1994).

Moreover, when land is abandoned because of migration or simply because it is not profitable to cultivate it, overgrazing can become a threat. In the case of poor producers who have few alternatives this poses a danger because a large percentage have small animals such as goats and sheep.[154] The *Solidaridad* program to mitigate rural poverty has now been transformed into the program called *Progresa*. It offers several lines of action, one of which is small loans for poor people (no collateral) specifically targeted to purchases of goats and sheep. This program may have negative effects quite contrary to the original policy objectives, as *campesinos* see their land damaged by the very animals that were supposed to help improve their livelihoods.

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[153] One example of this is provided by the Dust Bowl in the United States (an area covering more than 150,000 square miles encompassing parts of Kansas, Oklahoma, Texas, New Mexico and Colorado) where between 1880 and 1910, homesteaders increased the land's vulnerability to wind erosion as they replaced the plains' natural grasses by row crops, wheat and cattle grazing (Worster 1979).

[154] If grazing is carried out by cattle, the land may suffer compaction whereby the absorption of rainfall decreases, encouraging runoff, a loss of topsoil and increasing the risk of erosion.

Data from the 1994 *ejido* survey (Gordillo et al. 1994, 7.1) show that 37 percent and 35 percent of *ejidatarios* own goats and sheep respectively. More small *ejidatarios* own goats.[155] Goats and sheep tend to pluck the entire plant and root out of the soil, increasing risks of erosion.[156] Data show an increase in the percentage of producers who graze their animals in common lands from 25 to 31 percent between 1990 and 1994.[157]

A typical example of the above is provided by evidence from subsistence producers in the state of Oaxaca.[158] Here yields may reach 300 kilograms of maize, enough to meet household needs for up to three months. Corn must be purchased during the rest of the year. These producers must migrate to obtain the necessary income for these purchases (and, in many cases, to hire one laborer to gather the harvest at the end of the cycle if the migration season starts before the end of the entire productive round). The *Programa Nacional de Jornaleros Agrícolas* (a program designed to provide temporary employment for rural laborers, particularly in areas affected by drops in employment and variations in migration seasons) provides small loans for the purchase of goats.[159] But because the labor force has been greatly reduced by migration, surveillance of herds is handed over to children. Animal hoofs and the particular grazing mode may destroy terrace walls and ledges in a single season. If this damage is not repaired, terraces rapidly become useless and erosion resumes. The ensuing stress is part of a process increasing the vulnerability of small producers as their resource base deteriorates.

If corn production is abandoned on marginal lands as a consequence of falling corn prices, soil erosion may be slowed down. As land is left fallow during entire seasons, the quality of the epipedon will gradually be restored. Weeds and grasses will return and grow again and the root systems of these plants will arrest loss of topsoil and prevent erosion. Thus, for marginal lands, there may be a positive environmental effect.

Deforestation

Deforestation can also affect erosion. As indicated in Table 44, in fourteen of the nineteen states,[160] the extent of disturbed forest systems is higher than the national average. Some of these states are already experiencing serious erosion. Figure 16 shows the states with higher than average perturbed forest systems. These states are also in regions with greater precipitation (see Figure 1) and where much of corn production takes place on sloping land. Under these conditions, erosion will be aggravated.

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[155] The ratio of goat owners with more than five hectares of land to goat owners with less than five hectares is 0.87. This ratio increased from .52 in 1990, which means that the percentage of goat owners increased in tho categories of *ejidatarios* (those owning less than and more than five hectares).

[156] In a large part of Mexico's southern sierras there is evidence of an increase in goat herding in response to labor shortages and in the context of degraded institutions for resource management of common land (García Barrios and García Barrios, 1990).

[157] Gordillo et al. (1994, Table 7.4) provide data and indicators (grazing in common land) on this process.

[158] Personal communication, Ricardo Díaz Cruz, *Programa de Jornaleros Agrícolas* (Sedesol), 6 March 1997.

[159] For example, in 1996 horticulture production suffered in the northern states due to the drought. Needs for migrant labor were postponed, and in some cases, significantly reduced.

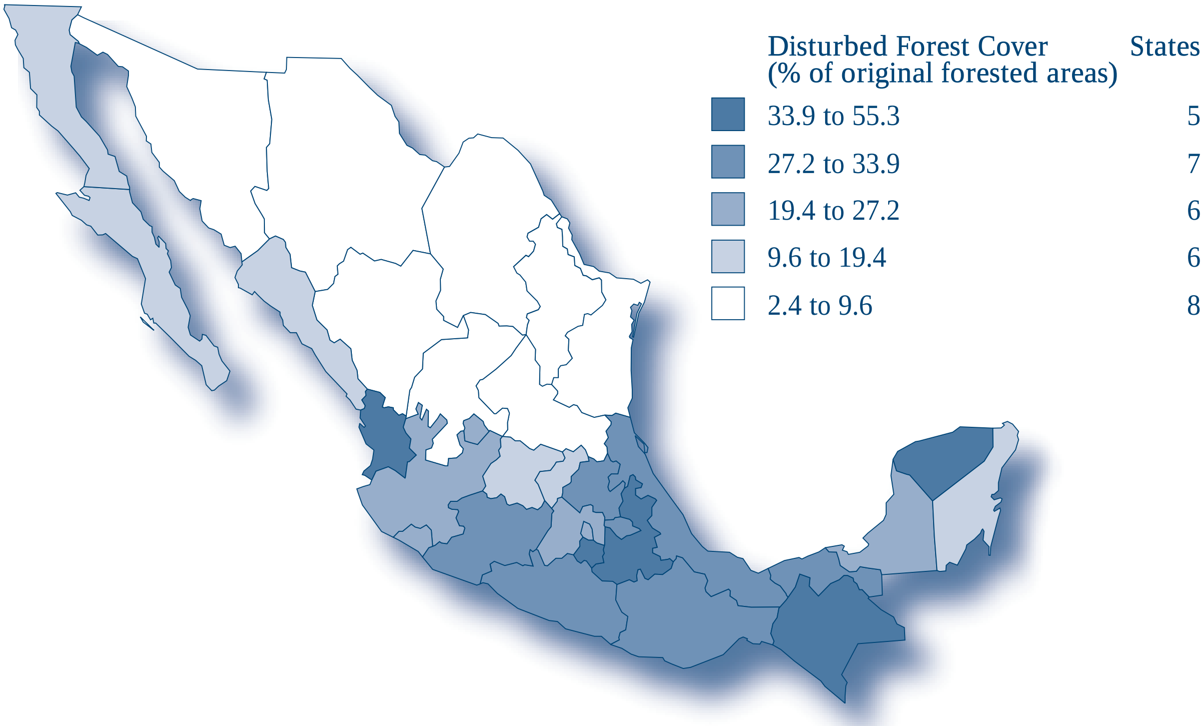
[160] Campeche, Colima, Federal District, Jalisco, México, Morelos, Nayarit, Oaxaca, Puebla, Quintana Roo, Tabasco, Tlaxcala, Veracruz, Yucatán.

Table 44 Total Forest Cover and Disturbed Forest Systems by State, 1994

State	(a) Total Forested Area (hectares)	(b) Total Disturbed Area (hectares)	(b) / (a)
Aguascalientes	189,562	43,190	22.78
Baja California	6,276,732	828,992	13.21
Baja California Sur	6,098,593	795,663	13.05
Campeche	4,661,783	1,196,728	25.67
Coahuila	13,468,254	745,794	5.54
Colima	315,659	66,048	20.92
Chiapas	5,148,104	1,801,522	34.99
Chihuahua	17,527,831	768,527	4.38
Distrito Federal	65,816	12,779	19.42
Durango	9,128,901	872,094	9.55
Guanajuato	1,039,454	127,579	12.27
Guerrero	5,281,116	1,719,541	32.56
Hidalgo	1,072,997	291,890	27.20
Jalisco	4,838,620	128,5093	26.56
México	894,613	225,974	25.26
Michoacán	4,206,451	1,355,878	32.23
Morelos	197,805	109,317	55.27
Nayarit	1,993,946	678,385	34.02
Nuevo León	5,196,346	128,820	2.48
Oaxaca	7,059,653	1,924,442	27.26
Puebla	1,698,722	627,722	36.95
Querétaro	737,821	111,550	15.12
Quintana Roo	4,732,325	888,219	18.77
San Luis Potosí	4,702,497	342,470	7.28
Sinaloa	3,722,037	654,987	17.60
Sonora	14581946	924,946	6.34
Tabasco	1,209,446	410,001	33.90
Tamaulipas	5,221,225	398,239	7.63
Tlaxcala	85,376	28,578	33.47
Veracruz	2,953,130	975,752	33.04
Yucatán	2,980,801	1,567,075	52.57
Zacatecas	4,457,607	327,679	7.35
National Total	80,214,486	12,137,292	15.13

Source: Semarnap Inventario Forestal periódico, *1994.*

Figure 16 Deforestation



Source: Semarnap, Inventario forestal periódico *1994.*

In addition, many of these corn-producing states where increased cultivated surface coexists with a reduction or marginal improvement in yields are the states where higher rates of fuelwood consumption prevail (see Figure 17). Such is the case in Veracruz, Oaxaca and San Luis Potosí, where rates of fuelwood consumption exceed the national average. The data in Figure 16 (and Table 45) indicate that the highest rates of fuelwood consumption tend to coincide with the corn-producing regions where plots are smaller, poverty is pervasive and production for self-consumption is prevalent. Poverty and consumption of fuelwood and other biomass to meet energy needs are tightly correlated.

Increased consumption of fuelwood can accelerate rates of deforestation and thus erosion. Fuelwood is already the most important item in consumption of wood and related biomass. Between 1989 and 1991 the consumption of fuelwood totaled 15.5 million cubic meters, of which industrial roundwood production was 7.9 million cubic meters and sawnwood 2.5 million cubic meters (World Resources Institute 1994).

The market dynamics of fuelwood consumption are also important. Consumption of fuelwood for cooking and heating depends on the prices of alternative sources of energy, particularly natural gas and fuel oil. For poor households, higher gas or fuel oil prices result in greater pressure on resources that provide fuelwood such as forests, shrubs and other biomass. Generally, populations that collect fuelwood do not replant.[161]

If corn prices are low, poor households that produce corn for self-consumption will have to rely to a higher degree on fuelwood if they can collect it directly. These producers have to rely on monetary flows even though, in the end, their overall corn account might balance. For these producers the pressure to rely on fuelwood increases as corn prices drop, which can contribute to loss of cover and greater stress on soil.

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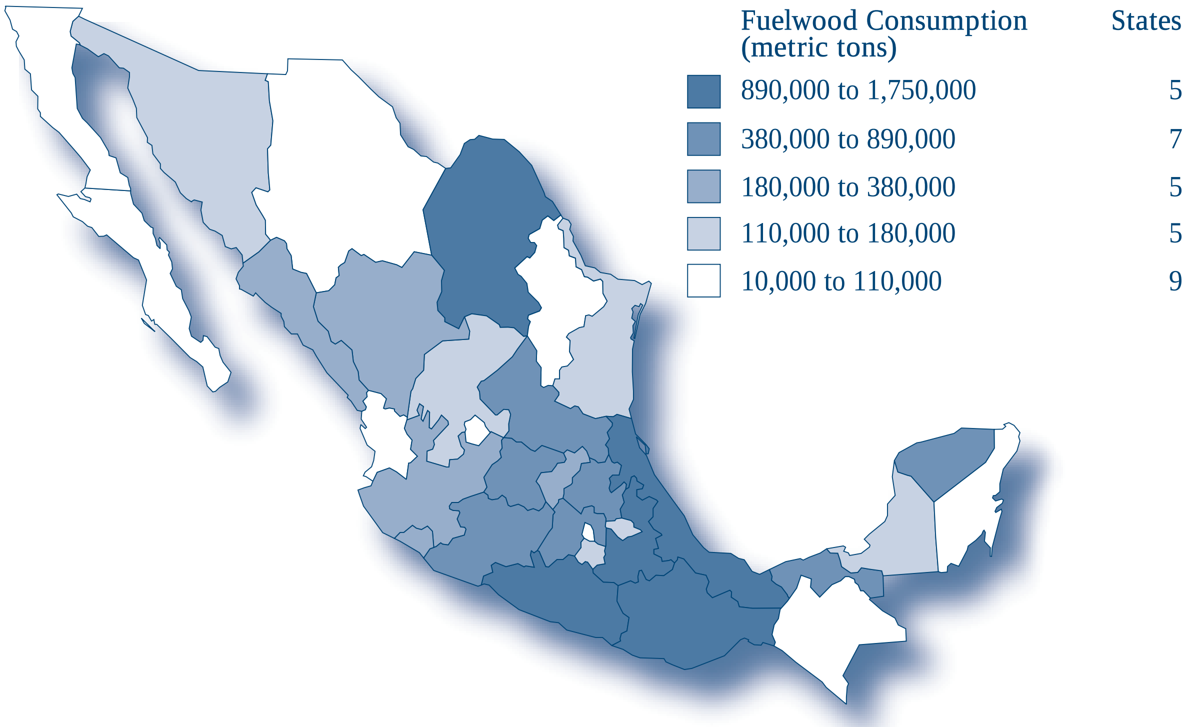
[161] The experience in India in small and medium-sized cities shows that when rural unemployment is severe, men and women are often tempted to engage in fuelwood collection in order to sell it in urban areas (Bowonder, Prassad and Unni 1988). These trends will worsen as the price of fuelwood increases.

Figure 17 Fuelwood Consumption



Source: XI Population Census, INEGI 1990.

Table 45 Residential Fuelwood Consumption

State	Metric tons/year
Veracruz	1,740,095
Coahuila	1,506,630
Oaxaca	1,451,021
Puebla	1,224,161
Guerrero	978,687
México	886,347
Michoacán	745,722
Hidalgo	608,381
San Luis Potosí	597,618
Guanajuato	571,946
Yucatán	406,576
Tabasco	380,190
Jalisco	338,367
Colima	231,814
Sinaloa	224,834
Querétaro	209,380
Durango	197,819
Zacatecas	175,136
Tamaulipas	169,317
Campeche	133,855
Tlaxcala	129,228
Sonora	117,540
Morelos	112,752
Nuevo León	108,816
Quintana Roo	108,074
Nayarit	82,582
Chiapas	67,088
Chihuahua	29,526
Aguascalientes	28,444
Distrito Federal	28,111
Baja California	16,898
Baja California Sur	19,450
National Total	13,626,405

Source: XI Population Census, INEGI 1990.

Thus, erosion is an issue in Mexico that pre-dates NAFTA. However, the agricultural sector, as it is evolving, is not necessarily arresting these trends. Indeed, if production processes become increasingly specialized with a focus on monoculture as a mechanism to enhance competition, erosion and soil degradation may be exacerbated. On the other hand, an increased reliance on methods that conserve soil could reverse those trends. Similarly, the importance of communities as stewards of the land may be critical.

B. Water

Water availability and use is one of Mexico's most important resource-management issues. There is already considerable stress on available resources due to overuse and depletion of existing underground aquifers, as well as from pollution of surface water bodies and aquifers. Production decisions in favor of crops that are more water-intensive, as well as more intensive in synthetic inputs that may accumulate in aquifers and surface water, will put additional stress on this resource. In order to prevent this, appropriate management techniques and policy instruments should be encouraged.

Water issues are very important in considering the impact of crop substitution and a potential movement to horticulture. They are also critical for understanding the future evolution of the corn sector because the development of irrigation is capable of providing the key to the increased competitiveness of Mexican agriculture. A significant proportion of corn growers in Mexico operating in rain-fed conditions show a clear potential which can be developed through irrigation. Irrigation is an important avenue for the introduction of technical change and diversification in Mexican agriculture.

Investments in infrastructure for irrigation in Mexico practically ceased in the early 1980s. Among the most serious environmental and resource management problems are over-exploitation of aquifers, build up of salinity levels, and pollution of surface and underground water bodies. Between 1945 and 1975, the total irrigated surface increased from 1.1 million hectares to 4.8 million hectares. But between 1975 and 1990, irrigated surface increased by an additional 570 thousand hectares. Between 1985 and 1990, only 80,000 hectares were brought under irrigated systems. Between 1990 and 1994, another 90,000 hectares were irrigated. Public investment in infrastructure for irrigation in agriculture stopped between 1988 and 1997, when Mexican agriculture faced increased foreign competition. Development of an irrigation infrastructure is vital to the modern sector as well as to intermediate producers (private and *ejidatarios*) who have the potential to increase yields.

The development of an irrigation infrastructure should go hand in hand with adequate systems to eliminate or minimize inefficiencies and waste in water management. Currently, close to 70 billion cubic meters of water are extracted from surface and underground water bodies to irrigate 5.4 million hectares. This means that on average 12,800 cubic meters of water are used per hectare. Under similar conditions of evapotranspiration and with similar crops, it has been estimated that the same yields could be attained with not more than 6,500 cubic meters. This means that high levels of waste are present either in the transportation system (canal network) or within the producing fields.

The level of waste in the big irrigation projects in Mexico's northwest is estimated by the National Water Commission at between 66 and 76 percent. The losses at each stage of the distribution network average 40 percent in the main distribution network, 12 percent in the secondary network (delivering water to each plot), and between 14 and 24 percent at the production unit (where sometimes very rudimentary systems are used to divert water into the irrigated zones). The level of efficiency is therefore extremely low at between 24 percent and 34 percent. Waste rates are higher in gravity irrigation (canals). Profitability of corn production on irrigated land varies. In a group of six basic crops (corn, wheat, rice, sorghum, beans and soybeans), 31 percent of the cultivated surface was not profitable. In the case of irrigated land with water from underground aquifers, this percentage rose to nearly 50 percent (FAO 1995).

Most water deposits have no revetment or coating to prevent filtration. Most water deposits are not treated to minimize evaporation. Drip irrigation continues to be the exceptional technique implemented by a very small minority of producers. Water management is a critical dimension of sustainable development in Mexico.

C. Air

Much of the modernization that will be brought about in the agricultural sector will rely heavily on pesticides and fertilizers to attain adequate productivity levels and quality standards. This could result in the accumulation of agrochemical residues (fertilizers and pesticides) and negative effects on workers' health. An indication of potential trends is provided by data in Table 46. In particular, the three most important states in terms of pesticide intoxications are the three top corn-producing states in Mexico. Central and Northern Jalisco and the southern part of Nayarit are regions where modernization of corn production is proceeding rapidly. Not only is agriculture by contract (futures sales) important here, but the use of the modern technological package (including laser technology, computer-assisted production and, of course, intensive use of pesticides) is fundamental in this process. In spite of the modernization of production activities here, application of pesticides is a major source of individual intoxications.

Under liberalized trade the modern corn-producing sector will continue to use the input-intensive technological package. Reliance on pesticides is a key element of this. Although prices of pesticides have been deregulated (and thus are not subsidized) the modern sector will continue to use these inputs. Modern producers may or may not improve the efficiency with which pesticides are applied as a result of higher prices. On the other hand, reducing risks for workers hired to apply pesticides implies purchasing gloves, masks, boots and protective vests (for backpack sprayers). It is not clear how much these additional costs will weigh in overall microeconomic considerations of modern corn producers. In addition, the restructuring contemplated for agriculture in Mexico under NAFTA involves producing goods which are oriented to markets where "blemish-free" produce is required. This implies production methods which are input-intensive.

An indicator would be useful to monitor pesticide use and exposure to pesticides in all states. This would allow for the determination of the role of pesticides and other chemicals in the modernization process, and their relationship to air quality.

Table 46 Cases of Intoxication from Exposure to Pesticides

State	1995*	%	1996	%	1997**	%
Aguascalientes	2	0.07	21	0.44	5	0.2
Baja California	49	1.81	65	1.37	31	1.2
Baja California Sur	57	2.10	23	0.49	15	0.6
Campeche	34	1.26	28	0.59	13	0.5
Coahuila	0	0.00	84	1.77	93	3.5
Colima	37	1.37	71	1.50	45	1.7
Chiapas	58	2.14	189	3.99	106	4.0
Chihuahua	40	1.48	35	0.74	64	2.4
Distrito Federal	4	0.15	7	0.15	6	0.2
Durango	26	0.96	131	2.76	64	2.4
Guanajuato	135	4.98	70	1.48	41	1.5
Guerrero	164	6.05	188	3.96	140	5.2
Hidalgo	26	0.96	41	0.86	14	0.5
Jalisco	258	9.52	947	19.97	482	18.0
México	128	4.72	97	2.05	70	2.6
Michoacán	177	6.53	388	8.18	83	3.1
Morelos	155	5.72	371	7.82	214	8.0
Nayarit	517	19.08	860	18.14	431	16.1
Nuevo León	4	0.15	14	0.30	22	0.8
Oaxaca	59	2.18	54	1.14	34	1.3
Puebla	65	2.40	132	2.78	40	1.5
Querétaro	52	1.92	62	1.31	26	1.0
Quintana Roo	15	0.55	39	0.82	34	1.3
San Luis Potosí	45	1.66	45	0.95	22	0.8
Sinaloa	70	2.58	265	5.59	177	6.6
Sonora	59	2.18	28	0.59	14	0.5
Tabasco	187	6.90	63	1.33	33	1.2
Tamaulipas	103	3.80	180	3.80	74	2.8
Tlaxcala	11	0.41	61	1.29	12	0.4
Veracruz	84	3.10	135	2.85	234	8.8
Yucatán	9	0.33	19	0.40	20	0.7
Zacatecas	79	2.92	29	0.61	12	0.4
Total	2709	100.00	4742	100.00	2671	100.00

* June–December.
** January–May.

Source: Author's compilation using data from Epidemiología, Boletín de la Secretaría de Salud, *vols. XIX–XXVIII.*

D. Biota

Because farmers in Mexico rely heavily on the wide variety of landraces available to them, and because Mexico continues to be a center of crop diversity in corn, it is important to examine the processes through which genetic erosion may be affected as a result of changing economic strategies and conditions.

Some government policies to assist adjustment to NAFTA (such as *Alianza para el Campo*) by promoting the adoption of improved OPVs and hybrids may be making inroads in some regions, displacing local landraces.[162] For example, the *kilo por kil*o policy in the *Alianza para el campo* program provides Pronase seeds (which are cheaper than the hybrids offered by Pioneer or other big companies). However, it is too soon to judge the net impact, as these producers may well return to the use of traditional landraces once the program is over.[163] A second policy being implemented and

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[162] Personal communication, J. MacMillan and Pedro Aquino (CIMMYT).

[163] The analysis of experience in the central depression of Chiapas is a good example of how hybrids specifically obtained for other areas in Mexico were introduced here. After a period of years, producers abandoned exclusively relying on these seeds and returned to their traditional landraces. Recombination of these advanced generations of improved varieties and hybrids with local seeds actually enriched varieties in some regions (see Ortega Paczka 1973). Later, however, re-introduction of hybrids (as research programs oriented to the needs of this region were implemented) has caused genetic erosion.

spreading rapidly in the countryside is the *"cesión de derechos"* program whereby producers entitled to a Procampo payment[164] authorize Procampo to make checks directly payable to seed companies for the purchase of hybrids. This is part of a system called "agriculture by contract" where producers are linked to suppliers of technology and intermediate inputs through a series of contracts which cover purchase of crops.

Production methods and modernization strategies including land use decisions will also have important implications for the genetic diversity of corn, including the potential loss of landraces and wild relatives. The large-scale diffusion of hybrids and improved varieties and the associated reduction of surface cultivated with local landraces can have an important impact on genetic diversity. This modernization process depends closely on the consolidation of varieties being used, resulting in the displacement of other varieties and wild relatives of corn such as *teosinte*. Where producers are expanding yields in the modern sector, local landraces may well be threatened. One study shows that modernization through the adoption of modern technology is taking place in particular regions such as Northern Guanajuato, Jaliso and Nayarit, where the use of hybrids and improved varieties was already common and where they did not rely on landraces.[165] Thus, an important indicator for ongoing monitoring is the introduction of hybrids in areas that traditionally relied on landraces.

Another threat to landraces and wild relatives comes from modern biotechnologies. A critical element of the modernization of the corn sector will likely occur through the increased use of transgenic crops. These are crops that are developed through genetic engineering. The widespread use of these seeds may intensify genetic erosion in two ways. The first is through the pressure to replace landraces with the new transgenic cultivars as the agricultural biotechnology industry intensifies its marketing operations.[166] Second, the transgenic material itself can be transferred to the crop's wild relatives.[167]

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[164] NP$556 per hectare.

[165] MacMillan and Aquino 1996.

[166] In several regions where improved varieties were able to outperform local landraces, displacement of the latter by the former has already taken place, in some cases as a result of crop substitution. The diffusion of transgenic corn may take this process to another stage if these new plants are able to withstand the stresses that have thus far hindered the further diffusion of hybrids. The differences between hybrids and improved open pollinated varieties on one hand, and bioengineered crops on the other, are such that it is conceivable that a further stage of genetic erosion may result from the expansion of cultivated surface with bio-engineered crops. Rissler and Mellon show convincingly that the approval of transgenic crops in the United States will not confer a seal of global safety to these crops. The most interesting example analyzed by these authors is the case of transgenic corn affecting corn's wild relatives (particularly *teosinte*). Under current regulatory procedures implemented in the United States, applications for approval of transgenic corn would be screened for two critical environmental risks (Rissler and Mellon 1996, 117–8): weediness of the corn plant itself, and the impact of the implanted genetic material in wild plant relatives. For corn cultivated in the United States these two possible risks will be unlikely. Because corn cannot survive without human intervention, the new varieties would not survive on their own and become weeds. And because there are very few wild relatives of corn growing within the United States, there is little or no chance of gene flow occurring. Thus, if there are no other hazards, these transgenic corn plants will be authorized and the seeds will be sold in the international market. In Mexico, particularly in a deregulated improved seed market, the new transgenic corn plants will be introduced by many farmers. The diffusion of these transgenic crops may take place at a faster rate as a result of increased pressure to modernize parts of the corn-producing sector. Because *teosinte* and corn can exchange genetic material, pollen from engineered corn will flow into *teosinte* populations and may produce negative effects. If some *teosinte* subpopulations become more resistant to pests, they will acquire an advantage over other subpopulations, crowding them out of their already small ecosystems and leading to genetic erosion in corn relatives. In other cases, the transferral of genes may lead directly to the extinction of *teosinte* subpopulations or allogamic depression (a reduction of the general attributes of an organism after hybridation, see Ortega Paczka 1977) may ensue and the rare wild species may become partially sterile as it combines with the common (transgenic) crop. In other cases, extinction of the rare wild species occurs as it loses genetic contents when it is assimilated by the common (transgenic) crop in various cycles of hybridation and introgression. In all of these cases, the relative abundance of the common genotypes leads to the extinction of the rare species (Arthur, 1994). This is why Berthaud and Savidan (1994, 48–49) note that releasing genetically transformed maize will make it crucial to find adequate answers to the questions of *teosinte* x maize gene flows.

A description of the regulatory system in the United States is presented and analyzed in Rissler and Mellon's account. One conclusion is that there is little room for protecting wild relatives of corn from the risks of bio-engineered corn. A study they quote recommends that bio-engineered corn be banned from areas where wild relatives coexist with transgenic corn. Another possibility would be for Mexico to establish a regulatory system that would allow it to screen transgenic crops in its own environment. This would require a strengthened regulatory capacity. For additional details, see Serratos, Willcox and Castillo 1995.

[167] The genes transferred to one plant from another organism will not necessarily remain static. Where crops are grown in proximity to wild relatives, and where open-air pollination takes place, the genetic material may drift to these other plants and mark their basic traits. These flows depend on physical barriers that separate plants, on chromosome endowment and compatibility, as well as time periods of flowering (Ortega Paczka 1977). If, for example, a corn transgenic plant has the capacity to resist droughts, and this material is transferred to wild relatives, the subpopulation of wild relatives may acquire these traits. In their own habitat, these new plant varieties will have the capacity to compete advantageously with other subpopulations of the same variety, or even against other plants, due to the newly acquired genes. In these cases, they will contribute to genetic erosion by displacing rare wild relatives existing in sparse numbers. The conclusions of the Rissler and Mellon study are supported by papers on genetic flows between landraces, improved maize varieties (including transgenic maize) and *teosinte*. See Serratos, Wilcox and Castillo (1995) and Ortega Paczka (1997).

The types of transgenic seeds that are created will be important. Many contemporary efforts in genetic engineering and in the development of hybrids and improved varieties are oriented towards making plants more pesticide and herbicide resistant, rather than pest resistant or plague resistant. These plants are thus designed to survive in the pesticide-saturated environment of modern capital- and input-intensive agriculture. Current trends seem to indicate agriculture based on bio-engineered plants will continue to require intensive use of agrochemical inputs. Moreover, the release of genetically engineered native organisms can lead to the hybridization and the development of new plant races, including weeds (see Rissler and Mellon 1996).[168]

Emerging biotechnologies are poised to have an important impact on corn production.[169] At present, there remain a number of obstacles to the adoption of biotechnologies. Limitations are posed by the small fraction of genes that have been identified and isolated and because characteristics that appear to be desirable by genetic engineers depend on a great number of genes.[170] Nevertheless, commercial applications of bio-engineered crops are being authorized. It is expected that the rate of growth of marketed transgenic plants will expand rapidly in the coming years (Rissler and Mellon 1996). Thus, an indicator to monitor the pervasiveness and characteristics of bio-engineered corn could be useful in determining its role in the modernization process.

The environmental effects of changes in land use are important in terms of effects on soils. The intensive breeding of a few economically important species may be the cause of further reduction in biodiversity. Just as in the case of modern crop plants, in forest plantations of commercial species the distribution of wild populations is substituted by populations in which genetic frequencies have been manipulated in order to meet certain requirements and, as a result, genetic variation is drastically reduced (National Research Council 1991). In some cases, the species that are selected for these plantations are the result of natural hybridization in which recombinant genetic material has given birth to new species or varieties with better adaptive features than both parents. Breeders tend to maximize adaptation of the new populations to large-scale plantation conditions by intensive selection for certain traits, often at the expense of genetic flexibility and the potential for future adaptive change. This negative aspect of plantations may be countered by multiple-population breeding strategies.[171]

To the extent that traditional production continues and even expands, genetic diversity may be protected. Traditional producers become the curators or fiduciaries of the stock of genetic resources that is the basis for their survival strategy. A recent study indicates that the penetration of the seed industry into the more traditional regions is not proceeding as quickly as was supposed by some, and that the traditional sector will focus on household production, thereby protecting landraces (see MacMillan and Aquino 1996). As of 1997, the widespread introduction of hybrids for corn production at the national level has not taken hold as common practice. There are only a few states in Mexico where use of hybrids in corn production exceeds 52 percent (see Figure 2 above).[172]

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[168] The system of screening transgenic plants through field trials will not be enough to identify these risks once commercial-scale application of these transgenic plants is approved. “Just because the original organism is a native species does not mean that it will be safe after it has been genetically engineered. Adding or deleting a gene from a native species may significantly alter its ecology, including the potential for increased pathogenicity” (Paoletti and Pimentel 1996, 670). In addition, approval of transgenic plants for commercial use in one country does not mean its use will be confined to that country. Transgenic corn already being approved in the United States will be used in Mexico’s corn sector (most probably in the modern sector).

[169] Emerging biotechnologies for maize include the following: genetic transformation through direct transfer of DNA (by microinjection, electroporation, bombardment of seeds with DNA-coated projectiles or bioballistics, agro-bacterium-mediated DNA transfer), cell and tissue culture, molecular genetic markers, photosynthetic enhancement (to increase share of yield in total biomass), plant growth regulators, and enhancement of nitrogen fixation. The latter requires the combined actions of genes in plants and in associated bacteria.

[170] As well, the transfer of these genes from one organism to another will face limitations as the recipient organism’s functions may be disrupted by the incoming genes.

[171] In the case of *Eucalyptus* (as with other species that grow at timberline in different parts of the world) the specific traits range from epicuticular wax arrangements on leaves to ectomycorrhizae in the tree’s roots which function as an extension of the root system (Raven et al. 1992). Besides, the introduction of plantations of species that are endemic to different environmental settings, such as *Eucalyptus*, may have serious consequences on the surrounding biota (Ezcurra 1997) because *Eucalyptus* can secrete toxins that kill insects which are not adapted to them, and has the ability to seek and use water in the subsoil in a most efficient manner. The expansion of large commercial plantations with this species may have serious environmental implications.

[172] Baja California, Baja California Sur, Coahuila, Colima, Jalisco, Morelos, Sonora, and Sinaloa.

Figure 2 indicates that the states where hybrid penetration has been very slow are those where upland production of corn is predominant, soils are frequently poor, and various risks prevail. In addition, those states where hybrids have not gained a strong foothold in corn production are those where the majority of corn-producing units are concentrated and where a greater proportion of poor producers operate (poor both in terms of income and their land resources). Use of hybrids and improved varieties of seeds is thus mixed in the traditional sector. The adoption of hybrids will continue to face the same technical obstacles as it did in the past. Landraces perform better in poorer soils and with more environmental stress. However, evidence for the Tierra Caliente region in Michoacan suggests that traditional subsistence producers under severe pressure may resort to improved varieties in response to official policies.[173] The rural development bank, Banrural, was instrumental in the introduction of several improved varieties.

Features of social organization also affect genetic diversity. Networks of social relations based on blood or ritual kinship, lineage, extended families, reciprocity, and other forms of association in traditional communities can be important contributors to genetic diversity. These relationships can provide the institutional support for production using certain types of corn varieties, either because of the nature of collective work involved in their use[174] or because of the positive externalities derived from production in collaboration with neighbors in phases of the productive process. This is particularly true in cases of strong dispersal of land plots owned by individual households.

Genetic diversity is also related to the presence of different indigenous groups for which maize cultivation is not only a means to ensure physical subsistence, but also part of a deeper social and religious process.[175] A poorly understood aspect of this interaction between social organization and genetic diversity of corn is the role of language in the conservation of traditional knowledge about corn seeds.[176]

Migration and technological regression will affect the ability of communities to conserve genetic diversity.[177] The associated phenomenon here is the loss of traditional technologies that are the basis for *in situ* conservation of genetic resources. The loss of traditional technologies may occur through abandonment of cultivation practices and gradual erosion of the social institutions required to maintain these technologies.[178]

The population of *campesinos* in Mexico's corn-producing regions where native landraces are predominant will not be in a position to undertake *in situ* conservation under conditions of economic duress. The deterioration of these producers' technological capabilities will undermine their capacity to conserve and develop genetic resources in the medium and long term. Every year, in the Spring–Summer cycle, and to a lesser extent in the Autumn–Winter cycle, approximately 1.5 to 2 million Mexican *campesinos* select the seeds that will be used in the following cycle. This calls for specific knowledge about seeds and agro-ecological conditions. This knowledge has no equivalent in formal institutional seed conservation programs. Not every member of the family of a corn grower or in the community possesses knowledge about the relationships between seeds and agro-ecosystems. The information has been gradually transferred from one

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[173] Personal communication, Víctor Suárez, ANEC.

[174] As in the case of *cajete* cultivation in Oaxaca's Mixteca.

[175] This relation between cultural variance and genetic variability has been studied by Ortega Paczka (1973) and Hernandez Xolocotzi (1985).

[176] An illustration of this strong interaction is provided by the *Mixe* language which identifies a greater and richer number of stages of plant development (such as germination, flowering, leaf and whorl development and, appearance of black color at base of kernels) than those existing in conventional scientific literature (Ortega Paczka 1997). Another illustration of the importance of vernacular language in conserving and transmitting these genetic resources from one generation to another in the case of Totonacan populations (in the states of Puebla and Veracruz) is provided by Cuevas Sánchez (1991). In many cases, plant variability is only identified in vernacular Totonacan, and the influence of formal schooling was negatively correlated with the capacity to identify plant variability.

[177] Examples of this process are many. In the Mixteca Oaxaqueña - the *"cajete"* system is being abandoned, and with it, the use of certain local cultivars (Ortega Paczka 1997, García Barrios et al. 1991). In the Puebla valley, producers have almost entirely abandoned a traditional system based on local varieties that were capable of germinating on residual humidity (the so-called *"arrope"* system) from sparse winter rains (Ortega Paczka 1997, 16). Varieties with very long maturity periods, such as the Tehua race in the Grijalva Valley, Chiapas, which has a ten-month cultivation period, are being abandoned. And varieties with extremely early maturation rates that were used to cover urgent needs for tender earcorn (*elotes*) are also being abandoned. In Yucatán, and many other regions, similar processes of genetic erosion are linked to the gradual elimination of intercropping practices that had additional positive effects on soil conservation.

[178] Cultural erosion is well documented in the literature (see, for example, García Barrios et al. 1991).

generation to another. When the chain is broken, either because corn production looses ground or is abandoned, that knowledge will be lost. *In situ* or dynamic conservation requires adequate standards of living for the individuals who are responsible for that environmental service.

Thus, crucial information regarding seed properties, selection criteria and procedures, as well as production processes can be lost as a result of migration.[179] In general, resource management information and knowledge will deteriorate if significant and sustained migration occurs. Where demographic structures are modified to a significant degree, with the passing away of the elder members of a community and the migration of middle-aged members, loss of information ensues as the capacity to identify crop variability fails to be transmitted.[180] Thus, social and cultural diversity go hand in hand with genetic diversity. If information on agro-ecological systems is lost, the loss of genetic resources may follow. If the institutions of collective resource management or the social support for cooperative labor are seriously eroded, information can be lost (Ortega Paczka 1997) and social institutions, which are the basis for highly diversified production systems relying on a wide variety of landraces, destroyed.

Social institutions that support technological alternatives where genetic variability is important are currently undermined by poverty and rural unemployment. While poor producers rely heavily on corn genetic diversity, it does not follow that if they remain poor they will continue as efficient curators of genetic variability. In fact, with poverty, their capacity to manage their productive resources (including genetic resources) is degraded. Household consumption of such resources is normally a condition that accompanies poverty and is frequently associated with migration. These conditions are not conducive to the conservation and development of genetic resources.

The definition of genetic erosion is of critical importance here. In a strict sense, maintaining genotypes in a germplasm bank implies that genetic information is saved or maintained. Theoretically, it can be used to enrich the gene pool of new varieties or hybrids. However, a more general and rigorous definition of genetic erosion must include loss of information on the use of these seed varieties, as well as irreparable erosion of the social and technological basis for production using the seed in question.[181] When this information is lost, or when the institutional base disappears, then genetic erosion takes place.[182] This sort of genetic erosion produces essentially the same result as when landraces are displaced by high-yield hybrids—the information associated with the traditional landraces is lost.

Genetic erosion is more related to the loss of information about genetic variability than it is to the loss of specific genotypes. If a social base that cultivated certain strains of landraces disappears, unless there is strong homology with either other groups or localities, the information about those landraces could also disappear.[183] Specific genotypes that are closely linked to certain agro-ecological traits are also dependent on certain labor and production practices and routines. When the social fabric that supports these routines is destroyed or degraded, the information on the specific links between seeds and environment (such as type of soil, humidity, plant intensity, and date for sowing) will eventually be lost and genetic erosion may occur.

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[179] Where producers operate in plots that are spread out over a certain amount of territory, this strategy based on genetic variability involves sowing different varieties in each plot as an insurance against factors that negatively affect production. Thus, landraces and genetic resources are decisive for producers' strategies.

[180] See for example Cuevas Sánchez (1991).

[181] Personal communication, S. Taba (CIMMYT) and Francisco Cárdenas (INIFAP), March 1998.

[182] This is comparable to what happens when tribal cultures disappear and information regarding specific plants' uses is lost. Thousands of years have elapsed and made possible a creative process through which extremely valuable information accumulated. When the cultures and lifestyles of these indigenous peoples are lost, all of this information is "forgotten" or irrevocably lost. Much of this information is transmitted orally, or informally in agricultural and other practices (such as medicine and leisure). There is no written record of many of these items, and when social institutions are destroyed or undermined, the information is lost.

[183] Ortega Paczka (1997) reports on this loss of technological capabilities in several instances. The inability to select and manage genetic resources is probably the initial symptom of this process. The inability to select the precise agro-ecological niches for sowing is the next step. Also related is the inability to determine the precise timing and other agricultural practices. A very important opinion is that of Hernández Xolocotzi in a study in 1971 (quoted by Ortega Paczka 1973, 33).

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Appendix A

A Note on the Literature on the Effects of Trade Liberalization and Corn in Mexico

The literature on the effects of trade liberalization on Mexico's corn producers includes econometric analyses with estimates on the corn-producing sector and computable general equilibrium (CGE) models of various characteristics. Among the latter are models used by Levy and van Wijnbergen (1992), and Robinson et al. (1992) which help estimate effects on agricultural production. A summary discussion of some of the relevant results is presented in Josling (1992). It is important to note that CGE models are useful for certain exercises, but the restrictions they impose on technologies and utility functions limit their usefulness in this context. Moreover, these models rely critically on the assumption that markets are always clear and are thus able to deploy their allocative properties. This assumption is without theoretical foundation, considering the results in stability theory and, in particular, the implications of the Mantel-Sonneschein-Debreu theorems (Debreu, 1974).

For a detailed analysis of the main shortcomings of the above, see the testimony in Stanford (1992) at the hearing of the USITC on economy-wide modeling of the implications of free trade. Moreover, as Brown (1992) recognizes, the dynamic impact of NAFTA may well dwarf the static impact analyzed by most applied CGE models. Kehoe (1992) notes that surprisingly little effort has gone into evaluating the performance of such models after policy changes have taken place.

The Levy and Wijnbergen (1992) study is a good case for this type of examination. This study uses data from several sources and years to estimate a total rural labor force of 6 million, with approximately 2.25 million maize producers. This latter figure is further disaggregated into 2 million "subsistence" producers and 0.25 million "large scale" producers. In addition, they estimate 3 million landless rural workers and about 0.72 million producers in the non-maize sector. They further estimate that out of the 2.25 million producers there are 787,000 net sellers and 1.46 million that are either net buyers or self-sufficient producers. They also argue that the net buyers probably buy a small share of the total maize consumed, "so that the benefit they receive from lower maize prices is positive, but probably small." This estimate is consistent with most studies of corn markets in rural Mexico that identify high transaction costs for purchasers of maize, as well as rigidities due to market failures or imperfections (such as segmented markets). This explains why benefits from price reductions are considered small. These studies' analyses indicate that there is a group of net sellers whose sales are relatively small, so that their losses from lower maize prices are not significant. The indirect wage-rate effect of lower maize prices is more important for this group.

Considering a total domestic production figure of 10.3 million tons (for the year 1989), Levy and Wijnbergen estimate the number of producers who will leave the maize-producing sector and the total land surface affected by this decision. Using an estimate of aggregate price elasticity of supply of maize of 1.5 for maize from irrigated land and 1.03 for rain-fed lands, and considering a price reduction of maize due to trade liberalization of 50 percent, they estimate a decrease in corn production from irrigated land of 0.97 million tons (from 1.5 million to 0.53 million tons) and of 4.5 million tons from rain-fed lands (from 8.8 to 4.3 million tons).

This contraction of maize output releases land and labor for other (presumably more productive) uses. Taking into account average yields of 2 and 1.4 t/ha for irrigated and rain-fed lands respectively, the output contraction in maize releases 320,000 hectares of irrigated land and 3.21 million hectares of rain-fed land.

Using old data on land-to-labor ratios by type of crop, the authors conclude there is a release of 75.58 million worker-days. They assume an average rural worker works for 180 days a year, leaving 419,888 workers released in the maize-producing sector, and that all irrigated land released from corn is devoted to other grains, fruits and vegetables and other crops in the same proportions as existed in 1989. This implies that 19.85 million worker-days will be required by non-maize production on irrigated land (see Table A-1).

Table A-1 Ratios of Land to Labor, by Crop and Type of Land

Land Characteristics	Maize	Other Grains	Fruits and Vegetables	Other	Pasture
Irrigated	51.5	25	165	23	N.A.
Rain-fed	18.4	9	58	18	5

Worker-days employed per year per hectare of land.

Source: Norton, R. and L. Solís, 1983. The Book of CHAC. Programming Studies for Mexican Agriculture. *Baltimore: Johns Hopkins University Press.*

Levy and Wijnbergen state that a "plausible scenario is that half of the released rain-fed land is devoted to pasture, with the remaining half equally divided between other grains and other crops (but not fruits and vegetables)." Non-maize production on rain-fed land would then require 29.6 million worker-days and there would be a net release of 26.13 million worker days which translates into 145,000 workers. The authors conclude that free trade in maize would put downward pressure on the rural wage rate and the number of workers released would be small when compared to the total labor force for 1989 (approximately 6 million workers).

The authors note that equilibrium in the rural employment market is restored as the fall in rural wage rate generates employment in maize and vegetable production until excess labor disappears. It is not clear where the increased production of maize takes place. They further note that released labor would be reabsorbed through direct interventions such as public works in irrigation. Finally, equilibrium is restored through migration.

Critique

Existing analyses of NAFTA effects and producers' responses rest on several basic assumptions. One is that producers affected by declining prices can modernize their production activities and become competitive. Thus, the substitution effect brought about by the change in relative prices is associated with technical changes (input and output mix) which generate welfare gains. If producers have access to the required resources, this is one possibility, as witnessed by the modern sector of corn producers. But to many commercial producers, resources such as good quality soils or water are not available. The scope of their alternatives vis-à-vis price reductions may not include continued operation in the corn-producing sector. There is no accurate information on how many producers who are corn sellers today are in this situation.

A second assumption is that modern corn producers have the flexibility to shift to horticulture, whose labor-intensive nature provides comparative advantages to Mexico. This may be a plausible assumption for modern corn producers, especially in irrigated systems in Northwest Mexico, where already well-established marketing channels exist. However, the number of hectares that can be successfully reallocated to horticulture is limited given the size of the regional market for these products. For these authors, approximately 30 percent of the released land under irrigation would be reallocated for other grains, 30 percent to fruits and vegetables, and 30 percent to cotton, tobacco and other crops. For land allocation patterns in 1989, this means doubling the cultivated surface in fruits and vegetables, a scenario hard to support given existing conditions (see Gómez and Schwentesius Rindermann, 1993).

A third assumption is that displaced laborers will be able to find adequate employment opportunities, either in the rural sector or in the urban markets. This view ignores the job deficit that has accumulated during the past years. It also overlooks the serious situation of rural unemployment and data on the evolution of real wages in both rural and urban sectors. This is an important issue for those people relying on remittances to supplement income losses or for those with urgent cash requirements who must sell part of their grain stock only to repurchase the same amount later from labor earnings.

A fourth assumption is that subsistence farmers will not be affected by the price reductions induced by NAFTA. This view ignores the fact that subsistence households are part of a market economy where monetary flows are required. Their alternate sources of income are important. Besides, the vast majority of these producers sell small amounts of their production throughout the year in order to meet very short term liquidity needs. Real wages have maintained a decreasing trend for three years now. And, as Levy and Wijnbergen conclude, rural wages will go down as a result of the declining trend of corn prices. Subsistence workers will find themselves under additional pressure from the point of view of their off-farm income generating activities.

Finally, this analysis of how producers will respond to changes in corn prices does not consider cross-price elasticities. Corn producers do not take decisions regarding the quantity of corn to be produced based only on its price. Their supply function includes other factors including the price of the labor force and the relative prices of other crops. The Levy and Wijnbergen study is based on a partial equilibrium approach "mostly because of the forbidding data requirements for a full-fledged general equilibrium model" (Ibid. 482).[184] But in the absence of reliable cross-price elasticities for corn, their approach fails to explain why the fall in corn prices coexists with the expansion of production.

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[184] In spite of the differences between the approaches, de Janvry treats the partial equilibrium approach of Levy and Wijnbergen as a general equilibrium model.

Appendix B

A Special Study of Migration and Corn-Producing Regions

In a special report for this project Salas (1997) evaluated potential migration of labor in corn-producing areas in Mexico. There is a lack of good data on recent migration patterns from rural areas of Mexico, and to evaluate the potential for migration of poor rural area dwellers, indirect methods need to be used.[185] By their nature, these methods do not allow for extremely accurate results, but they provide reasonable estimates of potential trends.

Salas uses two indirect methods. The first combines economic and demographic data to identify those states where poor and less productive corn producers are concentrated. By matching those data with data on the final destination of agricultural production in each state (consumption in the household, consumption in the domestic market) it is possible to identify regions where subsistence production predominates. The second method uses demographic data to identify attraction and expulsion areas. A comparison between rates of population growth at the national, state and municipal levels allows for the classification of states according to their potential for attracting migration from other states or producing emigration to other states. By combining the two analyses, it is possible to identify which corn-producing states show the greatest potential for generating migration.

The study initially undertakes a joint cluster analysis of four economic variables. The first two of these variables come from the 1990 Population Census, and they are the share of the total labor force that earns less than two minimum wages and the share of total population living in rural areas defined as towns and villages with less than five thousand inhabitants. The data for the third variable used is the proportion of agricultural units in each state whose production goes for consumption in the household. It is also a proxy for subsistence farming. The fourth variable is corn yield per hectare. The data for the third and fourth variables come from the 1991 Agricultural Census.[186]

The cluster analysis (Jobson 1992) relying on the four variables generates a classification of states that helps estimate potential migration.[187] Starting with two variables, labor income and rural population, and then adding the variables pertinent to subsistence units and relative productivity data, a hierarchy of states is built. A third set of clusters is built using the four variables to produce groups of "similar" states. With this classification, a new variable is added: permanent migration at state level. The crucial test is if, by adding this variable, the resulting clusters are different. If that is the case, emigration would be a sort of "outlier" in terms of the other variables already considered.[188]

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[185] A good discussion of Mexico-United States migration estimates can be found in Corona and Tuirán (1997).

[186] This Census uses 1990 data.

[187] Since three of the four variables are already in a percentage format, the fourth variable had to be transformed into the ratio of each state's corn yield per hectare to the national corn yield per hectare. This transformation is an order-preserving function and makes data on productivity compatible with the rest of the data.

[188] In the final report, I will include the results of a logistic regression which estimates the odds of being a net migration zone as a function of the four variables used here.

Table B-1 shows the data base used for this section of the analysis. The results of cluster analysis are straightforward. Using Euclidean metric as a measure of proximity the data show the distance between states and reveal a certain concentration among the southern states of Mexico of low productivity and small plots of land producing corn. Data on the volume of permanent migration at state level (Partida, 1994) is then introduced to test the efficiency of the clustering technique. The initial clusters are quite robust: after adding a fifth variable (the state's share in total emigration in the period from 1980 to 1990), the clusters listed in Table B-2 remained stable. The association between states characterized by permanent immigration or emigration tends to be close in the terms of the cluster analysis. An important point is that the states in groups 6 and 7 are among the less-developed in terms of social development; cluster groups are also characterized by similar levels of agricultural production for the household as well as corn production yield per hectare.

Table B-1 Clusters of States by Social and Corn Production Characteristics

State	Cluster	Technology	State	Cluster	Technology
Chiapas	1	Less developed	Aguascalientes	3	Mixed
Guerrero	1	Less developed	Campeche	3	Mixed
Hidalgo	1	Less developed	Coahuila	3	Mixed
Michoacán	1	Less developed	Chihuahua	3	Mixed
Oaxaca	1	Less developed	Durango	3	Mixed
Puebla	1	Less developed	Guanajuato	3	Mixed
Querétaro	1	Less developed	Jalisco	3	Mixed
Quintana Roo	1	Less developed	Nayarit	3	Mixed
San Luis Potosí	1	Less developed	Nuevo León	3	Mixed
Tlaxcala	1	Less developed	Sinaloa	3	Mixed
Baja California	2	Developed	Tabasco	3	Mixed
Baja California S.	2	Developed	Veracruz	3	Mixed
Colima	2	Developed	Zacatecas	3	Mixed
Sonora	2	Developed	Distrito Federal	4	Low Technol.
Tamaulipas	2	Developed	México	4	Low Technol.
			Morelos	4	Low Technol.
			Yucatán	4	Low Technol.

These results, however, are not entirely satisfactory since the clusters do not allow for a predictable grouping of states, at least in terms of development and the structure of corn production. To correct this problem, another set of production variables is introduced to build a typology of development and corn production by using data at the state level.[189]

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[189] Special crosstabs from the 1991 Agricultural Censuses are used to build new clusters.

Table B-2 Cluster Analysis of States: Migration and Four Socio-Economic and Corn Production Related Variables

State	Cluster	Migration Trend
Baja California Sur	Group 1	Immigration
Sonora	Group 1	Immigration
Baja California	Group 2	Immigration
Jalisco	Group 2	Immigration
Nayarit	Group 2	Emigration
Sinaloa	Group 2	Emigration
Aguascalientes	Group 3	Immigration
Coahuila	Group 3	Emigration
Colima	Group 3	Immigration
Chihuahua	Group 3	Immigration
Morelos	Group 3	Immigration
Tamaulipas	Group 3	Immigration
Distrito Federal	Group 4	Emigration
México	Group 4	Immigration
Nuevo León	Group 5	Immigration
Quintana Roo	Group 5	Immigration
Oaxaca	Group 6	Emigration
San Luis Potosí	Group 6	Emigration
Yucatán	Group 6	Emigration
Zacatecas	Group 6	Emigration
Campeche	Group 7	Immigration
Chiapas	Group 7	Emigration
Durango	Group 7	Emigration
Guanajuato	Group 7	Immigration
Guerrero	Group 7	Emigration
Hidalgo	Group 7	Emigration
Michoacán	Group 7	Emigration
Puebla	Group 7	Emigration
Querétaro	Group 7	Immigration
Tabasco	Group 7	Emigration
Tlaxcala	Group 7	Immigration
Veracruz	Group 7	Emigration

The data used includes social characteristics (such as the share of national population, population in rural areas, levels of income) as well as corn-producing characteristics (the proportion of units devoted mainly to corn production, average size of plots, use of hybrids, the share of total production that is consumed by the producer himself). The typology is constructed by means of a cluster analysis, the details of which can be found in Salas (1997).

As Table B-1 shows, in this typology Chiapas, Guerrero, Hidalgo, Michoacán, Oaxaca, Puebla, Querétaro, Quintana Roo, San Luis Potosí, and Tlaxcala assemble in a group of less-developed states. An important common feature of all of these states is the level of poverty, as implied by a large share of the labor force with low income levels, combined with a high proportion of corn-producing units with technologies that are not capital intensive (the proxy used is the low usage rate of hybrids) and high rates of corn production for household consumption.

In terms of permanent migration, Chiapas, Querétaro, Quintana Roo and Tlaxcala have a positive social rate of growth, i.e., they attract population. But this happens only at the state level, since every one of them has at least one urban area that has been growing quickly in the past ten years or more. A disaggregated analysis, at the municipal level, shows that most municipalities show the opposite behavior by expelling population. This means that there is a close link between the level of development (social and productive) and permanent migration in Mexico.

Next, in order to evaluate these findings, a principal component analysis is conducted. The results show that 75 percent of the total variability of the social and economic variables used as explanatory factors of permanent migration can be accounted for through a pair of composite variables grouped under the label "social and corn-producing structure." The factor matrix is reproduced below in Table B-3 and shows the combination of variables that form the pair of factors. factor 1 captures a set of positive developments in the social and economic structure of the areas studied. The second Factor captures the negative side of the involved variables. While a component in Factor 1 is positive and has a relatively high value, the corresponding component in Factor 2 reverses those values.

Table B-3 Factor Matrix for the Composite Variable "Social and Corn Production Structure"

	Factor 1	Factor 2
Area	0.73061	-0.02403
Consumption	0.88989	0.28199
Hybrid Usage Rage	-0.87757	0.15099
Income	0.79625	-0.36293
Population	0.34907	0.75296
Rural	0.54368	-0.74604
Corn-Producing Units	0.78889	0.41943

Using the results of this principal component analysis, a logit regression was conducted to estimate how is the overall level of social development, combined with the structure of corn production, is a good predictor of migration. Also, the odds ratio estimated in the logistic regression show that a one-unit drop in the level of economic and social development implies a 0.43 rise in the odds, that is, the ratio of probability of emigration to probability of immigration = 0.43.

As Table B-4 shows, lower income levels and traditional corn-producing techniques are associated with higher definitive migration probabilities.

Table B-4 Migration Probabilities of the Variables

Variable	Probability
% of corn growing area	positive
% of production for self-consumption	positive
% of units using hybrid corn	negative
% of income less than 2 mw	positive
% of total population	positive, but relatively small
% of rural population	positive
% of units with less than 5 ha	positive