NAFTA and Conservation of Maize Diversity in Mexico[1]

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Executive Summary

NAFTA and internal agricultural reform in Mexico

Ever since negotiations for a North American Free Trade Agreement (NAFTA) got under way, its effect on the Mexican maize sector and the conservation of maize diversity has been a subject of debate. Our purpose in this paper is to look back at this debate and compare the facts and the forecasts. We review the commitment to liberalize the North American maize market, the actual policies undertaken to this effect, and the evolution of maize output, imports and consumption in Mexico. Then, we address two associated threats to *in situ* conservation of maize in Mexico: the extinction of subsistence maize agriculture and the spread of maize transgenes in maize's center of diversity.

It is hard to distinguish the effects of NAFTA from those of concurrent internal reforms and those attributable to the macroeconomic instability experienced in Mexico from 1994 to 1996. Government involvement in the grain (staple) sector characterized Mexican development policy from the mid '30s to the early '90s, but this came to an end this last decade. Since the dismantling of Conasupo in 1999, government involvement in the sector is reduced to retail sale of maize through the Diconsa network, the allocation of maize imports, and the Kilo-por-kilo program. NAFTA scheduled an end to barriers to Canadian and American maize exports. While maize seed imports were completely liberalized in 1994, other maize was subject to gradual liberalization ending in 2008.

One of the most important internal reforms was the dismantling of Conasupo and its disappearance in 1999. Its closing put an end to guaranteed producer prices and abolished government purchases and commercialization of both domestic and imported maize. In 1991, Aserca was created to take the place of direct government involvement through Conasupo. Aserca operates an "indifference price" program where producers sell their crops to industry at the international price, and the government pays them the difference with an accorded price. Three years after the establishment of Aserca, Procampo was created as a transitional program: it is scheduled to conclude in 2008, when free trade is achieved. Procampo consists of decoupled (*i.e.*, area-dependent and unlinked to productivity) income transfer to landowners. The transfers remains if the beneficiaries turn into alternative crops. Alliance for the Countryside (*Alianza para el Campo*) is another program created to increase agricultural output, capitalize producers, and promote agricultural efficiency through crop substitution.

Another fundamental reform was that of Article 27 of the Mexican Constitution, designed to grant property rights to the *ejidal* sector. The reform put an end to land distribution and the ban on the *ejidal*-land market. Promotion of the land market was meant to help capitalize agricultural activities by giving peasants access to the private-credit market and allowing private investment in agriculture. Curtailment of government involvement in agriculture was also accompanied by the disappearance of state-owned companies linked to this sector. Finally, along with agricultural policy changes a social program (*Solidaridad*, *Progresa* or *Contigo*) was created to assist the rural poor.

Macroeconomic models of liberalization consistently predicted a sharp increase in maize imports and a sizable reduction of the Mexican maize sector. Maize imports have increased following NAFTA but, surprisingly, domestic maize production has also increased—particularly in rain-fed maize areas, where the area grown in maize has

expanded. In contrast, the supply of maize from irrigated areas has managed to remain constant only through an increase in productivity. Ongoing statistical analysis finds no statistical evidence of a significant change in the trend of Mexican imports during the last 20 years. This implies that factors other than NAFTA have influenced the variation in maize imports. These factors might include changes in the exchange rate, in domestic demand for maize, and in agricultural price policies. If we compare the NAFTA years with the previous three years, the domestic price of maize has followed the downward trend of international prices in a period characterized by minimal fluctuations in the real exchange rate and little government intervention. However, there have been sharp short-term fluctuations in prices due to changes in the real exchange rate and in international prices. Fluctuations of the exchange rate are fundamental in explaining sharp changes in governmental intervention in the maize market every two years, as well as in explaining changes in maize output and imports.

Conservation of maize diversity in Mexico

NAFTA and internal agricultural reform were expected to curb subsistence maize agriculture in Mexico, thus threatening *in situ* conservation of Mexican maize landraces. Expectations have not been realized and there is yet no indication of the abandonment of subsistence maize agriculture in Mexico. Research suggests prices changes might have worked to restructure the maize sector in some regions, away from commercial agriculture and into a subsistence practice, conserving local maize diversity. Some still see a threat to maize conservation in Mexico, while others refute it. Differences in opinion arise not from analysis of macroeconomic data, but from alternative microeconomic interpretations of farmers' responses to price changes. One hypothesis suggests that rain-fed-maize farmers have not experienced price changes due to their isolation from the market, but they will cease production if prices continue to fall. The other holds that the rain-fed maize sector has already restructured in response to price changes; yet subsistence farmers will continue growing maize despite further price decrease.

Many questions remain unanswered, but current research should reduce concerns raised by the Commission for Environmental Cooperation's previous environmental assessment of NAFTA. Also associated to maize imports from the United States, the spread of maize transgenes to this crop's center of diversity in Mexico has emphasized the need for an *in situ* conservation program. Costs are a fundamental aspect of *in situ* conservation, which was considered economically infeasible for many years. The cost of conserving landraces depends on the efficiency of a conservation strategy, which in turn is contingent upon the research to support it. There is no need to permanently subsidize traditional agriculture as an umbrella for conservation. A more efficient strategy is to address specific threats to conservation individually. This will allow limited but specific responses to threats.

It is fundamental to establish a monitoring and research program that will enable us to detect and respond to contingencies. A well-funded monitoring and research program is the soundest way to reduce the costs of crop genetic resources conservation *in situ*. Areas in need of research are cultural change and loss of indigenous values. Also of concern are changes in land tenure following the reform of Article 27 of the Mexican

Constitution. A monitoring program must be designed to alert us of changes in the status quo of landrace management by detecting long-term processes—such as cultural change and land consolidation—but also more rapid developments such as the spread of transgenes. Ongoing work in the states of Oaxaca and Chiapas holds promise, but work must be extended to the rest of the country.

The National Survey of Rural Households in Mexico—ENHRUM—recently gathered countrywide information on the life and house-economy of families living across the countryside this year. This includes extensive information on local and regional maize markets. ENHRUM also collected a wealth of information on the management of maize in rural homes, which includes—for the first time ever—data on the extent of maize seed networks across the nation. In association with researchers in the University of California and El Colegio de la Frontera Sur, ENHRUM collected a nationally representative maize sample.

1. Introduction

Ever since negotiations for a North American Free Trade Agreement (NAFTA) got under way, its effect on the Mexican maize sector and the conservation of maize diversity have been subject of debate. Our purpose in this paper is to look back at this debate nearly a decade after NAFTA came into effect. We set to task comparing the facts and the forecasts. We review the commitment to liberalize the North American maize market, the actual policies undertaken to this effect, and the evolution of maize output, imports and consumption in Mexico.

Research on the effects of NAFTA must account for the extensive concurrent reforms of the Mexican economy. The liberalization of trade was part of a wider set of policy reforms set in motion prior to NAFTA and since then. Mexican agriculture—and particularly the maize sector—experienced reforms destined to reduce government involvement in the sector and to create new agricultural institutions. A series of nationwide policies were also implemented to help producers in the grain and oilseed sectors face competition. Moreover, it is hard to distinguish the effects of NAFTA and internal reforms from those attributable to the macroeconomic instability experienced in Mexico from 1994 to 1996.

The paper is divided into four sections. In the following section, we describe Mexico's obligations under NAFTA as regards the liberalization of maize, the agricultural-policy reforms and the expectations of those in government. We also describe the trends in Mexican maize output and imports, as well as recent empirical analyses of those trends. Finally, based on these results, we present alternative hypotheses as to why expectations have not been met. In section 3, we use this information as backdrop to reflect on the conservation of maize diversity in Mexico following NAFTA. We first describe the evolving concept of crop conservation and the research supporting it. Then, we address two threats presumed to arise in Mexico due to growing maize imports from the United States: the extinction of subsistence maize agriculture and the spread of maize transgenes in maize's center of diversity. We conclude by sharing our prospects and recommendations for the conservation of maize diversity in Mexico.

2. NAFTA facts and forecasts

Government involvement in the grain (staple) and oilseed sectors characterized Mexican development policy from the mid '30s to the early '90s. Agricultural policy included guaranteed producer prices for staples, aid for grain storage and commercialization, and subsidized credit and insurance. The Mexican government was also involved in production and sale of subsidized fertilizer and seed of modern varieties (MVs); and it controlled imports. All of this changed during the past decade. Since the dismantling of Conasupo in 1999, government involvement in the sector was reduced to retail sale of maize through the Diconsa network (now formally part of the Secretariat of Social Development—Sedesol); the allocation of maize imports, and the Kilo-por-kilo program, part of the *Alianza para el Campo* (of the Secretariat of Agriculture, Livestock and Fisheries—Sagarpa).

2.1 Trade liberalization and NAFTA

Although Mexico became part of the General Agreement on Trade and Tariffs (GATT) in 1986, there were no major changes at that time in the protection given to the maize sector: import licenses remained in place until the implementation of NAFTA in January 1994 and the Uruguay Round in 1995. NAFTA put an end to the barriers to Canadian and, especially, American maize exports. Mexico signed two different agricultural agreements: one with Canada and the other with the United States. Agricultural trade liberalization also benefited members of GATT participating in the Uruguay Round.[2]

Maize seed imports were completely liberalized at the start of NAFTA, but other maize was subject to a gradual liberalization scheme that will end in 2008. The scheme—tariff rate quota—consists of a tariff-free quota and a fixed tariff on above-quota imports. The initial quota was based on trade volumes between Mexico and its North American partners during the 1989–1991 period. In 1994, the quota was set at 2.5 million metric tons for the United States and 1 thousand metric tons for Canada, and the above-quota tariff was set at 215 percent (or US$206.4/metric ton). Every year, the quota is raised and tariffs reduced until they are abolished in 2008. Until 1999, the full quota was allocated to Conasupo, the livestock-feed industry and private maize processors. The Secretariat of Agriculture and Conasupo would estimate the amount of maize imports required by the latter to accomplish its functions (grain storage and supply to tortilla producers under the subsidized-tortilla program, see below and Shagam and Plunkett 1997). Up to 2000, the Mexican government did not collect the above-quota tariffs whenever the quota was exceeded.

In negotiations with its North American partners, Mexico introduced a clause that protects its interests on certain agricultural products, including maize. The clause can be used as a "mechanism to counteract" imports whenever they constitute a "serious threat" or cause "important damage" to a certain sector. Whenever this happens, Mexico can either stop reductions in tariffs or use the import quota set in 1994. As regards its commitments with the World Trade Organization (previously GATT), whenever "imports rise due to low import prices," the Mexican government can establish additional import restrictions.

2.2 Domestic reforms and government expectations

One of the most important internal reforms—as regards agricultural policy—was the dismantling of the National Company for the People Subsistence (*Compañía Nacional de Subsistencias Populares*—Conasupo) and its disappearance in 1999. Conasupo's closing put an end to guaranteed producer prices and abolished government purchases of maize (both domestic and imports)[3] and its commercialization; it also put an end to subsidies to consumers of tortilla. In 1991, a new government agency, Aid and Services to Agricultural Commercialization (*Apoyos y Servicios a la Comercialización Agropecuaria*—Aserca) was created to take the place of direct government involvement through Conasupo. In its early years, Aserca dealt only with wheat and sorghum; it

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[2] Naturally, Mexico also gained access to foreign markets through NAFTA and GATT. We confine our analysis to trade between Mexico and the U.S., which is the main source of Mexican maize imports.

[3] Up to the late '80s, Conasupo purchased more than 80% of maize imports, but only 15.7% between 1994 and 1996 (see Yúnez-Naude and Barceinas 2000).

incorporated maize in 1997. Aserca operates an "indifference price" program that does not have nationwide coverage. Instead, every region operates under a specific scheme that consists of a pre-harvest "price agreement" for each crop based on international prices and transport costs. Thus, producers sell their crops to industry at the international price, and the government pays them the difference with the accorded price.[4]

Up to 1994, the Agricultural Council decided guaranteed prices for maize and beans to be administered by Conasupo. In 1995, devaluation of the peso allowed the Zedillo administration to transform Conasupo into a "last-resort" buyer for these two crops, eliminating price supports. Conasupo did not import maize that year, and its participation in the domestic market was reduced from 45 to 20 percent. After the drop in the international price of maize in 1996, Mexico followed an intermediate price-fixing scheme that established regional prices halfway between the guaranteed and the international prices. This was called the "base price" (Aserca 1997:10, 13-14). The price support scheme changed again in the 1996/1997 winter season. Conasupo would now pay "indifference prices" for maize and beans, according to the source region. Prices were set at the average international price (based on the Chicago Commodity Exchange) plus transport costs to Mexican ports and operating (storage, transport, financial) costs (Sagar 1997:22). Under this scheme, Conasupo became again (and until its disappearance in 1999) a "last resort" buyer for white maize for human consumption. That is, it allowed producers to sell their maize wherever they could find a better price within the private sector.

Records show that Conasupo's participation in the domestic maize market (especially for white maize) decreased during its final years. In 1993 and 1994, Conasupo purchased around 45 percent of the domestic output; in 1995, its purchases decreased to 20.3 percent; to 8.8 percent in 1996; 19 percent in 1997, and 12.5 percent in 1998 (<www.sagarpa.gob>). During its two final years, Conasupo sold exclusively to mills (*nixtamaleros*) and tortilla producers. Conasupo would sell maize at a price that allowed *nixtamaleros* to retain a "reasonable" profit from the sale of tortillas at a subsidized price. Millers would also get a cash subsidy for the maize they purchased directly in the domestic market at "prices linked to internationally prices (Zedillo 1997)." This subsidy allowed them to retain a "reasonable profit," large enough to support the subsidized tortilla program—which ended along with CONASUPO.

Three years after the establishment of ASERCA, a transitional program called Procampo was created. Procampo came into effect during the 1993/1994 winter season—merely months before NAFTA. Procampo substituted previous price supports. It consists of an income transfer to landowners who grow or recently grew barley, beans, maize, cotton, rice, sorghum, soybean, safflower and wheat. Procampo's main goal is helping domestic producers of staples face competition from the United States and Canada, or turn into more competitive crops. It is scheduled to conclude in 2008, when free trade is achieved. Transfers to producers are decoupled: they are area-dependent and unlinked to productivity. The transfers are maintained after beneficiaries turn into alternative crops.

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[4] In addition to indifference prices, a price coverage scheme in international markets was implemented for several staples, including maize. In 1996, 1.7 million metric tons of maize were covered under this scheme in New York's and Chicago's Commodity Exchange (Zedillo 1996).

Besides Aserca and Procampo, the Zedillo administration (1995-2000) created a program called Alliance for the Countryside (*Alianza para el Campo*). Its main purpose was to increase agricultural output, capitalize producers, and promote agricultural efficiency through crop substitution (fruits and vegetables for staples) wherever there was a competitive advantage. Alianza's two characteristics are its decentralized nature and a fund that producers help capitalize <www.sagarpa.gob>. Alianza includes Procampo as well as other programs. As regards maize, one of the programs is "Kilo-por-kilo", which provides producers with MV seed in exchange for own seed.

Curtailment of government involvement in agriculture was accompanied by the disappearance of state-owned companies linked to this sector. Besides Conasupo, fertilizer, seed and other companies supplying inputs to agriculture were either closed or privatized. Subsidized government credit was also reduced. Another fundamental reform was that of Article 27 of the Mexican Constitution, promoted by the Salinas administration, in 1991, to grant property rights to the *ejidal* sector. The reform put an end to land distribution and the ban on the *ejidal*-land market. Promotion of the land market was meant to help capitalize agricultural activities by giving peasants access to the private-credit market and allowing private investment in agriculture.

Along with the policy changes intended to support agriculture, the Salinas administration created the Secretariat of Social Development (*Secretaría de Desarrollo Social*—Sedesol) and its social program, *Solidaridad*, specifically design to assist the rural poor. The Zedillo administration later renamed the program *Progresa*, and President Fox changed it once again to *Contigo*, after extending it to urban poor.

A decade ago, the outcome of NAFTA and internal reform was anticipated as follows:[5]

1) Maize imports would rise following reductions in tariffs and other barriers.
2) Mexican producers would have to compete with foreign producers.
3) Competition would results in greater efficiency and land productivity in maize.
4) This would trigger
- A drop in the domestic price of maize
- A decrease in the domestic supply of maize
- The loss of maize diversity.

5) Migration out of rural areas would increase.
6) Land would consolidate in larger production units.

2.3 Trends and analytical results

Maize imports have increased following NAFTA as expected, but contrary to expectations domestic maize production did not drop unexpectedly (Fig. 1). Increases in total output are tied to the growth of output in rain-fed maize areas, where the area grown in maize has expanded over the past few years (Figs. 1 and 2). In contrast, the supply of maize from irrigated areas has managed to remain constant only through an increase in productivity (Fig. 3). Overall, only irrigated areas have experienced a downturn in production as imports increased.

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[5] A more extensive discussion of forecasts pertaining to NAFTA can be found in Yúnez-Naude 2002, www.worldbank.org)

The numbers show there has been an erratic upward trend in maize imports, which suggests NAFTA has not brought about structural change of imports. It is noteworthy (Fig. 4) that the value and volume of imports climbed fast in 1996 only to drop as sharply in 1997 and recover in 1998; the volume of imports remained relatively unchanged after 1998 while their value dropped slightly. Ongoing statistical analysis of the structural change of imports (valued in constant dollars) between January 1980 and August 2002 suggests there has been no such change (Barceinas and Yúnez-Naude 2002). That is, there is no statistical evidence there has been a significant change in the trend of Mexican imports during the last 20 years. This implies that factors other than NAFTA have influenced the variation in maize imports. These factors might include changes in the exchange rate, in domestic demand for maize, and in agricultural policies (as regards domestic prices).

A different study gauges the divergence between domestic and international prices, based on the "law of one price," and throws light on governmental involvement in maize markets (Yúnez-Naude and Barceinas 2002). The method used disaggregates percent changes in the real domestic price of a good—i.e., maize—into three components: percent change in the international price, percent change in the real exchange rate of the peso against the U.S. dollar, and a residual that captures change attributable to domestic policy. Results of this price analysis (Table 1) show that during the end of the import substitution period (1983-90 with respect to 1977-82) the real term devaluation of the peso (25 percent) and government involvement (10 percent) isolated the domestic price of maize (-0.6 percent) from the drop of the international price (-41 percent). The results are reversed in the following period (1991-93 with respect to 1983-90): the appreciation of the peso (-20 percent) and the liberalization of maiz (-25 percent) prevented its domestic price (-24%) from following the increase in international price (21 percent). The '90s crisis (1995-96 against 1993-94) was characterized by a marked devaluation of the real exchange rate (39 percent), that isolated the domestic price (0.08 percent) from the drop in the international price (-40 percent) and, as we have seen, this allowed the government to refrain from affecting prices (0.09 percent). The situation changed radically during the following period (1997-2000 against 1995-1996): as the peso appreciated (-33 percent), greater intervention (30 percent) did not stop the domestic price from dropping (40 percent) following the descent of the international price (-37 percent). If we compare the NAFTA years with the previous three years (1994-2000 against 1991-93), we can see that the domestic price of maize (-35%) has followed the downward trend of international prices (-35 percent) in a period characterized by minimal fluctuations in the real exchange rate (0.05 percent) and little government intervention (10%).

These results show that notwithstanding a trend towards less governmental intervention in the maize market after NAFTA, there have been sharp short-term fluctuations in prices due to changes in the real exchange rate and in international prices. Macroeconomic instability—as in wide fluctuations of the exchange rate—is fundamental in explaining the sharp changes in governmental intervention in the maize market every two years, as well as in explaining changes in maize output and imports.

2.4 Some hypothesis

We briefly describe a series of hypotheses to explain why domestic maize production has not dropped following NAFTA as expected. These hypotheses are discussed in greater extent in relation to the conservation of maize diversity, in the next section. As mentioned, domestic maize output has not decreased primarily due to greater productivity in irrigated areas and a larger maize acreage in rain-fed areas. This is explained by the highly heterogeneous conditions in which maize is grown and the various uses given to maize. In broad terms, irrigated maize is mainly destined for the market, while a large proportion of rain-fed maize is for self-consumption. Irrigated maize is produced commercially, while rain-fed maize is a family activity. We suggest only the former has been affected by maize liberalization as expected. However, this group has benefited from the programs operated by *Aserca* and *Alianza para el Campo*. Support from these programs, along with higher productivity, explain why irrigated maize has been able to compete with foreign producers. It is not entirely clear why the rain-fed maize producers have not responded as expected.[6] There are two basic hypotheses. The first suggests that most producers in rain-fed maize areas have not been affected by the liberalization of maize since they are subsistence growers isolated from the market. The second suggests that the rain-fed maize sector has been affected by liberalization, and it has restructured in response by transforming into a largely subsistence activity.

3. Conservation of maize diversity

3.1 **In situ** *conservation in perspective*

Calls to conserve crop genetic resources (CGRs) in the early twentieth century were finally heeded by the United Nations Food and Agriculture Organization (FAO) in the 1960s (Harlan 1975). At that time, a sense of danger pervaded the scientific community (see Frankel 1970). The southern leaf blight epidemic of 1970 finally exposed the vulnerability of genetically homogeneous modern varieties (MVs) and revealed the importance of traditional crop varieties or *landraces*, as sources of genetic diversity (NRC 1972).[7] These were the years of the Cold War and a steady agricultural supply was a matter of national security in the United States and the Soviet Union. In developing countries, the rapid spread of "technological development" (modern crop breeding), from the advanced countries of the world, threatened to disrupt local centers of crop diversity in a matter of years, displacing landraces. Scientists called for action (Frankel 1970; Wilkes and Wilkes 1972; Harlan 1975; Hawkes 1980). Their call was timely, but there was also a sense of urgency. Farmers could not be held back in an "outdated system" indefinitely (Frankel 1970).

[6] The small size of output handled by this type of producer turns it uneligible for Aserca, and their lack of financial resources prevents them from participating in *Alianza para el campo* shared fund (see bellow, FAO and Sagar 2000). Taylor *et al*. (1999) explore the effects of price changes in communities with isolated maize markets. Most producers in rain-fed areas hold very little land. According to the 1990 Agricultural Census, more than 55% of farms under 5 hectares are strictly subsistence (Hernandez Estrada, 2000).

[7] Throughout the paper, the term "landraces" is used to refer to traditional crop varieties, while the term "varieties" is used when it applies to both MVs and landraces.

Among others, Frankel (1970) called for an inventory of CGRs in farmers' fields, which would provide guidelines for "planning and concerted action" for conservation. "Action" meant collection and preservation of CGRs in storage facilities away from centers of diversity. This conservation strategy, known as *ex situ* conservation, was the safest and cheapest alternative, and most importantly, it would insure the accessibility of CGRs to breeders (Frankel 1970; Wilkes and Wilkes 1972). A handful of scientists, skeptical about the safety of seed repositories, brought forward the benefits of conserving CGRs *in situ* (e.g., Wilkes and Wilkes 1972; Iltis 1974); but for most of those concerned, this was an impractical, unaffordable, or simply unacceptable alternative. Forcing farmers to keep "primitive" varieties posed insurmountable ethical, social and economic obstacles (Frankel 1970; Hawkes 1980; Myers 1979). Moreover, MVs were meant to replace landraces. MVs would alleviate *technological constraints* on world crop production and reap the gains of efficiency. Little was known, at the time, of the way in which farmers manage or use crop diversity, but that was beside the point. Conservation was conceived then as the painstaking preservation of genetic structure, and this was best done by literally freezing CGRs (Frankel 1970; Iltis 1974). Preserving this genetic structure in the field, if at all possible, would have required strict scientific supervision in experimental stations (Frankel 1970; Wilkes and Wilkes 1972).

By the early 1980s, a global network of gene banks for major crops was largely in place, managed by the Consultative Group on International Agricultural Research (CGIAR) and sponsored by FAO, the World Bank and the United Nations (Harlan 1975; IBPGR 1981; Ruttan 1982; Plucknett *et al*. 1983). Important national collections were also expanded or created during this period (Harlan 1975). In contrast, *in situ* conservation had not been implemented anywhere nor funds been set-aside for this purpose (Prescott-Allen 1981; Oldfield and Alcorn 1987). *In situ* conservation was now advocated by a growing sector of world society that appreciated its advantages — the UNESCO-MAB Program, the US National Research Council, and subsequently the United States' State Department (Oldfield and Alcorn 1987); but it was strongly disavowed by others (IUCN-UNEP-WWF 1980 in Oldfield and Alcorn 1987; Ford-Loyd and Jackson 1986 in Brush 1992). Agronomists and breeders coincided that *in situ* conservation was suitable for *wild* progenitors of crops or for "difficult" material such as recalcitrant species and trees, but it was not applicable to crops themselves (Hawkes 1980; Prescott-Allen 1981; Hanson 1984; Palmberg 1984; Ingram and Williams 1984). A decade after its original proposal, *in situ* conservation of CGRs was still deemed unfeasible (Frankel and Soule in Altieri *et al.* 1987; Frankel 1983 in Oldfield and Alcorn 1987; Ingram and Williams 1984; Brush 1986; Altieri *et al.* 1987): "The interventions […] required for the survival of landraces would be too extensive" (IBPGR 1985).

During the 1980s, even supporters of *in situ* conservation expected that agricultural modernization and commercialization would ineluctably eradicate landraces (Brush *et al.* 1981; Brush 1986; Altieri and Merrick 1987; Altieri *et al.* 1987; Oldfield and Alcorn 1987). Early exceptions were Hernández and Ortega (1971), who knew that modern maize varieties introduced in Chiapas, Mexico, had been incorporated into households' crop repertoires, rather than substituted landraces. They attributed the persistence of varietal diversity to the existence of *socioecological niches* suited to specific varieties, precluding their mutual displacement. Their findings came in the early 1970s, when diffusion of modern maize varieties in Mexico had stagnated (Hewitt de

Alcantara 1976), but in the 1980s, agricultural modernization and MVs suddenly became again the linchpin of Mexico's rural development policy (Barkin 1987; Ochoa 2000). Thus, three decades into the Green Revolution, MVs became again a threat to landrace conservation (Brush *et al.* 1988).

Anthropologists and ecologists in the 1980s remained optimistic about *in situ* conservation. Their optimism was based on greater appreciation of farmers' knowledge, and it eventually bloomed in several proposals to implement and fund *in situ* conservation. Research on peasants' life strategies showed that crop diversity is the cumulative product of centuries of deliberate management for diversity of diet and stability of income (Alcorn 1981, 1984; Brush *et al.* 1981). It also became evident that peasants had a role as much in creating as in maintaining diversity and that they were, in fact, the most accomplished *de facto* curators of crop diversity (Brush 1986; Oldfield and Alcorn 1987). It was also realized that management of crop diversity is dynamic: the diversity of farmers' crops is constantly changing in response to the environment in which they produce — a strategy for subsistence in a socially and physically heterogeneous environment that has persisted to our time (Brush *et al.* 1981; Altieri and Merrick 1987). Finally, research showed that, in order to conserve CGRs *in situ*, traditional practices have to be preserved. This seemed to suggest that farmers could be recruited for *in situ* conservation—through adequate compensation.

Proposals for funding in situ conservation came and went. Myers (1979) saw the political feasibility of charging a levy on commercial seed companies to fund compensation—others did not see this possibility (see Frisvold and Condon 1998). A different proposal was to have governments subsidize and protect traditional agriculture in Biosphere Reserves, focusing on indigenous groups willing to maintain their traditions (Oldfield and Alcorn 1987). Yet another proposal was to integrate conservation and agricultural development as an alternative economic strategy in underdeveloped areas (Altieri *et al.* 1987; Oldfield and Alcorn 1987; Brush 1992a). When economic turmoil in the 1980s forced many peasants in Latin America back into subsistence agriculture (Collier and Mountjoy 1988 in Brush *et al.* 1988; Altieri and Anderson 1986 in Altieri *et al.* 1987; Fox 1992; Hewitt 1994; Collier 1999), a substantial group of scholars saw an opportunity to advance sustainable, small-scale subsistence agriculture as a means of betterment, as a tool against environmental degradation, and (by keeping diversity accessible) as a way to end peasant dependency on capitalists and middlemen (Nabhan 1985; Altieri *et al.* 1987; Oldfield and Alcorn 1987). *In situ* conservation played a key role in this scheme that seems to endure in some circles.

At the same time, growing difficulties for *ex situ* conservation generated a more orthodox interest in *in situ* conservation (Goodman 1990). Collections and their operating costs had grown exceedingly fast so in spite of obvious deficiencies in existing collections, there were pressures to putt off "indiscriminate" collection (Holden 1984, in Oldfield and Alcorn 1987; IBPGR 1985; Plucknett *et al.* 1983). Equally important, it became evident that the removal of crops from their original cultural-ecological context halted adaptive evolutionary processes, rendering frozen CGRs vulnerable to new pests and diseases (Nabhan 1985; Oldman and Alcorn 1987; NRC 1993).

Breeders' opposition to *in situ* conservation of CGRs persisted into the 1990s, but eventually it eroded (NRC 1993; Maxted *et al.* 1997). Today, it is widely held that *ex situ* and *in situ* conservation are complementary strategies (see e.g., Morales *et al.* 1995;

Dempsey 1996; Maxted *et al.* 1997; Wright 1997; Jarvis *et al.* 2000). *In situ* conservation of CGRs is now endorsed by the international community; the United Nations expressed its support through FAO and the Convention on Biological Diversity (Diversity 1996). Nevertheless, this widespread support has not translated into implementation. To this day, proponents of *in situ* conservation face two challenges: devising a practicable strategy and finding a source to fund it. The association between these two challenges has not been fully appreciated in the literature.

Recognition of farmers' contributions in conserving, improving, and making CGRs available to others mustered a new debate on farmers' rights (see e.g., Kloopenburg and Kleinman 1987). Proponents of farmers' rights advocate a mechanism to compensate farmers and support their continuing contributions (FAO 1989). Although FAO agreed to establish a fund for genetic resource conservation as early as 1991, funding has been slow in coming (Frisvold and Condon 1998; Brush 1998; Fowler 2002). Moreover, it is still uncertain how funding will be allocated when it finally becomes available. Concerns that *in situ* and *ex situ* conservation must compete for this funding have polarized their proponents anew, sparking a debate on their relative costs and benefits (Frisvold and Condon 1998; Gollin and Smale 1999; Evenson *et al.* 1998). The debate is mired by our incapacity to assess those costs and benefits, which relates directly to the other challenge for *in situ* conservation: a practicable strategy.

Planning for *in situ* conservation was delayed in the past by lack of research on traditional farming systems (Altieri and Merrick 1987; Brush 1992a; NRC 1993). The institutions working for CGR conservation during the 1980s did not pursue this research, and later emphasis on farmers' rights contributed little to filling the vacuum (Brush 1989; 1992a). In 1992, Brush pointed out two research areas in need of immediate attention: farmer attitudes toward crop diversity and patterns of change in their management of diversity. Since then, research on the economics of the household has contributed to an understanding of the first of these issues. We have learned much about which types of households conserve CGRs *de facto* (see, e.g., Aguirre *et al.* 2000; Brush *et al.* 1992; Bellon and Taylor 1993; Meng 1997; Perales 1998; Smale *et al.* 1999; Van Dusen 2000; Dyer 2002). However, we have made scant progress on the second issue outlined by Brush: we know little about how management of varieties and their diversity has changed, or how it evolves in response to a changing economic environment.

It is widely assumed that the central and most expensive aspect of *any* strategy for *in situ* conservation is creating incentives for households to maintain diversity (Myers 1979; Brush 1980; Dempsey 1996; Brush and Meng 1998; Frisvold and Condon 1998; Gollin and Smale 1999; Jarvis *et al.* 2000). Brush and Meng (1998) suggest that to minimize these costs, incentive programs must target households that are most likely to maintain crop diversity; but the actual cost of such programs is still a matter of speculation. Economic theory suggests that farmers will agree to conserve CGRs if they are compensated for their opportunity costs. However, those costs are nil today, since farmers maintain diversity of their own accord, that is, farmers willingly cover the costs of *de facto* conservation. Thus, anticipating changes in farmer attitude is essential to detect specific threats to *in situ* conservation and reduce its funding requirements. Unfortunately, there is virtually no research on specific threats to conservation, and our ability to predict them is extremely limited. We also cannot assess with any degree of certainty the potential costs of *in situ* conservation.

Despite these gaps in our knowledge, until recently, there was a widespread conviction that *de facto* conservation of CGRs was inversely associated with economic development, and particularly with market integration (Brush, *et al.* 1992; Bellon and Taylor 1993; Meng 1997; Smale *et al.* 1999; Jarvis *et al.* 2000; Van Dusen 2000). The scope of that association between conservation and development was very wide, as it included the development of goods, services, and factor markets, as well as basic infrastructure. The conviction influenced our appreciation of the potential costs of *in situ* conservation and its political feasibility. It was assumed that, as rural areas developed, farmers would cease to conserve CGRs, the incentives for *in situ* conservation would grow and be required in perpetuity. We now review the state of our knowledge and then address the threat to Mexican maize diversity posed by NAFTA.

3.2 The research

In situ conservation of CGRs is defined as "the continued cultivation and management of a diverse set of crop populations by farmers in the agroecosystems where the crop has evolved" (Bellon *et al.* 1997). There are three aspects to crop management: seed flow, seed selection and storage, and varietal selection. Ecologists and social scientists described crop management as a strategy to cope with risk and environmental heterogeneity and a way to satisfy diverse consumption needs (Clawson 1985; Nabhan 1985; Brush 1986; Brush *et al.* 1988; Bellon *et al.* 1997). Since the beginning of agriculture, specific varieties have solved the concerns of farmers and their households; diversity has accumulated as no single variety satisfies all of farmers' concerns. However, the social and economic developments of the 1980s seemed destined to obliterate farmers' concerns and the need for diversity with them (Altieri and Merrick 1987; Brush 1986, 1989; Oldman and Alcorn 1987). Economic analysis was called in to understand farmers' decisions (Brush 1989).

Economic research on the adoption of modern varieties (MVs) sought to identify barriers to their diffusion in developing countries to keep the Green Revolution going. A large body of knowledge (i.e., adoption theory) emerged from this research on varietal choice, concluding that farmers in developing areas face a variety of constraints (e.g., lack of credit, infrastructure, or information) that prevent them from adopting MVs. Theory suggested that some of these constraints (e.g., financial and information) would dissolve with the diffusion process itself, but the process could also be hastened through investments in infrastructure, research, and extension (Feder *et al.* 1985). Adoption theory provided a foundation for the emerging research on farmer management of diversity, which thus embraced varietal choice as its main subject, oblivious of seed flow and seed selection. The emphasis on varietal choice was warranted at a time when MVs were developed as a substitute to landraces and *landrace displacement* was perceived as the main threat to *in situ* conservation.

Agronomists and social scientists first suggested how farmers' choice of crops is shaped by various *concerns* over daily life, including environmental heterogeneity, pests and pathogens, risk management, culture and ritual, and diet (Hernández 1985; Bellon 1996a; Rice, *et al.* 1998; Jarvis *et al.* 2000). Then, scientists teamed with economists who built their findings into "household models", promising a more rigorous analysis and forecasts not possible in previous approaches. In the process, households' *concerns* over daily life were replaced – in our interpretation – by the economic *constraints* they face.

This was not the product of novel insight into farmers' thinking, but merely an unintentionally assumption of optimization models. That assumption, nevertheless, influenced our interpretation of the facts for years. We assumed that farmers conserved crop diversity because they had no choice, and we unwillingly ignored the role of culture in their choices. Our ignorance of farmers' preferences is the price paid.

Studies on varietal choice enriched our understanding of household management of diversity. Seminal studies were those of Brush and his colleagues (Brush *et al.* 1988; Brush 1989; Brush *et al.* 1992) and Bellon and Taylor (1993), who first suggested the type of analysis later followed by others. Also influential was Smale *et al.* (1994), who proposed the estimation of *inclusive*, reduced-form models that nest different explanations of farmer behavior as special cases. Inclusive models test for determinants of varietal management empirically by regressing household behavior and diversity outcomes, on the left side of the equation, with an assortment of variables representing constraints and other "farmer characteristics" (see Dyer 2000, for a review). Work with inclusive models includes Bellon (1996b), Meng (1997), Smale *et al*. (1999), Van Dusen (2000) and Bellon and Risopoulos (2001).

An association between infrastructure development and market integration with loss of diversity was often inferred from inclusive models of crop diversity. The inference was based on the proposition that trade (the result of infrastructure development and market integration) favors specialization and undermines diversity; but no evidence from an actual process of market integration backed it. Brush *et al*. (2000) and Dyer (2000) challenged this association of economic development and loss of diversity for widely different reasons. Ample reference to those reasons is made below.

As mentioned, largely absent from studies on crop diversity is culture (Brush and Meng 1998). Its influence has sometimes been inferred from the association between crop choice and farmers' characteristics. The empirical pattern is fairly consistent in the case of age, which is positively associated with the maintenance of landraces (Bellon and Taylor 1993; Meng 1997) and varietal diversity (Meng 1997; Van Dusen 2000), and negatively associated with a tendency to adopt MVs (Brush *et al.* 1992; Bellon and Taylor 1993; Bellon and Risopolous 2001). The influence of the head of household's age on crop choice is thought to derive from his or her consumption preference for traditional varieties. However, studies on consumption are rare (but see Subramanian and Deaton 1996), and little evidence has been published to back this proposition.

Research on farmer management of crop diversity—largely done at the University of California and the International Maize and Wheat Improvement Center (Centro Internacional para el Mejoramiento de Maíz y Trigo—CIMMYT)—developed into a well-accepted framework for *in situ* conservation. Its emphasis on varietal choice was endorsed by the International Plant Genetic Resources Institute (IPGRI) in its Training Guide for *In Situ* Conservation (Jarvis *et al.* 2000). Brush and Meng (1998) and Jarvis *et al*. (2000) believe a conclusion of this research is that farmers continuously act under numerous constraints, although the specific set of constraints on them may change constantly (Brush and Meng 1998; Jarvis *et al.* 2000). This supports the *niche* hypothesis, which suggests that since no single variety satisfies all of a farmer's concerns, there is a *niche* (or multidimensional space) in farmers' way of life in which particular varieties are protected from mutual displacement or exclusion (Bellon and Brush 1994; Rice *et al.* 1998). This agricultural analogy of the ecological niche was first used by Hernández and Ortega (1973), and it was extended by Brush and Meng (1998) using Tillman and Pacala's (1993) dissertation on natural ecosystems. According to this work, multiple species can co-exist where two or more factors are constraining and there are trade-offs in species performance—which is believed to be the case of crop varieties in marginal areas (Bellon and Brush 1994). The niche is thus construed as a safety net that prevents the displacement of landraces by MVs.

Exponents of the niche hypothesis conclude that the outlook for now is positive (Brush and Meng 1998), although economic development will one day threaten *in situ* conservation (Meng *et al.* 1998b; Smale *et al.* 1999; Jarvis *et al.* 2000). The niche hypothesis was born only three decades ago out of concern that MVs would displace landraces; but the significance of this threat to Mexican maize has been diminished since then by two developments. First, the release of MVs capable of out competing landraces in marginal environments has slowed down substantially (Jansen *et al.* 1990; Morris 1998, Perales 1998; Knight 2003). The private sector has taken over much of the commercialization chain for MVs in Mexico (Dempsey 1996; Morris 1998; Aquino 1998), and the prospects for agricultural intensification in marginal areas are not encouraging. Second, NAFTA's advent threatened to displace subsistence maize agriculture altogether—a threat that inclusive models of crop diversity cannot address. To take the analogy of the ecological literature further, research has been preoccupied with the competitive displacement of crop varieties, when a much greater threat—their mass extinction—looms over the horizon.

3.3 Maize and NAFTA

Macroeconomic models of trade liberalization consistently predicted a sizable reduction of the Mexican maize sector under a wide variety of scenarios (Robinson *et al.* 1993; Levy and van Wijnbergen 1994). Levy and van Wijnbergen (1994) expected substantial efficiency gains out of reallocating rural workers to more productive industrial jobs in the cities. Robinson *et al.* (1993) concluded that the liberalization of industrial trade alone would attract rural workers to better paying jobs in urban Mexico and in the United States, thus exacting a toll on Mexican agriculture and maize production. Findings coincided in predicting that if industrial growth and rising urban wages could entice workers out of rural areas, the removal of agricultural trade barriers would drive rural wages down, forcing workers to migrate due to lack of alternatives. Growth in the fruits and vegetables sector could not be expected to absorb all labor forced out of the maize sector. Around half a million workers could be expected to migrate out of rural areas as a result of complete trade liberalization (Robinson *et al.* 1993; Levy and van Wijnbergen 1994).

Boyce (1996) and Brush (1998) were the first to realize that liberalization of the maize sector would endanger Mexican maize landraces. Other government initiatives (e.g., the 1992 Land Reform) also imperiled *in situ* conservation of maize (Dyer and Belausteguigoitia 1996). The government administration that called for the preservation of crop diversity in the Rio Conference (Raeburn 1992; Diversity 1996) failed to protect maize resources from its own policies. The liberalization of the maize sector did not go exactly as planned and, as we have seen, forecasts were well off the mark. Critics still see a threat to maize conservation in Mexico (Nadal 2000; Ortega and Castillo 2000; Public Citizen 2001). Some of the claims are inadmissible, as they are based on outdated forecasts (see Public Citizen 2001). Others are based on the realization that those forecasts were wrong, and they use the work of de Janvry *et al.*'s (1995) as a point of departure (see CEC 1999; Nadal 2000). De Janvry *et al.*'s criticized macroeconomic models of maize liberalization in Mexico, saying that heterogeneity among maize producers would dampen the sector's response to a decrease in price. Levy and van Wijnbergen (1994) had incorporated some of this heterogeneity in their macroeconomic model, allowing for the fact that households with irrigated land could turn into alternative crops more readily than households with rain-fed land. Not surprisingly, they concluded that the latter would suffer disproportionately from liberalization and would likely leave rural areas altogether. Like Levy and van Wijnbergen, de Janvry *et al*. anticipated that the brunt of maize's liberalization would fall on rain-fed farmers, but they expected that, within this category, only commercial growers would respond to a decrease in prices, while subsistence farmers continued to produce in isolation from the market.

De Janvry *et al.* (1995) and Key *et al.* (2000) contend that subsistence producers find buying and selling inconvenient: transporting produce to and from the market can be costly and then, it might be difficult to find a suitable trading partner. Thus, producers are reluctant to participate in the market. Their hypothesis is supported by econometric evidence that "transaction costs" restrict the participation of Mexican maize growers in the market (Key et al. 2000). There is indeed a vast historical record of the difficulties faced by small-scale Mexican farmers in selling their surplus maize. Middlemen have long exploited these difficulties, often taking advantage of government efforts to solve them—such as support prices and marketing subsidies (Heath 1987; Fox 1992). However, there are no reports in the literature that suggest rural households have any difficulty buying maize. Maize markets are not the product of recent economic development; they have been part of Mexican *plazas* for centuries. More recently, when Mexico lost its self-sufficiency in maize in the early 1970s, the government strived to ensure that rural households had adequate access to maize. It consolidated the national supply network, Diconsa; the number of its stores increased dramatically during the 1980s, reaching nearly 25,000 by the early 1990s (Riera 1993; Hewitt 1994; Ochoa 2000). Until 1999, Diconsa had access to cheap imported maize through Conasupo and delivered maize to the countryside at controlled prices, substantially improving access to this staple. Private merchants have also contributed to the supply of maize in the countryside (García and García 1994; Hewitt 1994; Toledo *et al.* 1994). Therefore, it is unclear that "transaction costs" have played a decisive role in keeping producers growing maize for self-consumption.

A basic tenet of de Janvry et al.'s argument is that it is still more profitable for subsistence farmers to grow their own maize than to purchase it in the market. This is not consistent with a substantial body of evidence that rain-fed maize agriculture has been largely unprofitable in Mexico since the 1970s (Hewitt 1994).[8] Financial accounts of this sector show that although the value of production is often greater than the monetary expenses incurred, it is generally insufficient to cover the costs of family labor in maize (Heath 1987; Inzunza 1988; García and García 1994; Toledo *et al.* 1994;

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[8] This is purportedly the reason that government credit institutions finally ceased to finance most rain-fed maize growers in 1989 (Hewitt 1993; Fritscher 1999).

Evangelista 1998; Perales 1998; CEC 1999; Collier 1999).[9] It is likely that the sector's profitability has decreased even further following NAFTA. Data suggests this is the case in the state of Puebla. The work of Inzunza (1988), Evangelista (1998) and Dyer (2002) provide points of reference before and after NAFTA, albeit in different villages within the same region. In 2000, only 61 percent of households in the village of Zoatecpan expected to recoup their monetary expenses in *milpa*, compared to 93 percent found by Inzunza (1988) in neighboring Nauzontla.[10] Only 18 percent of Zoatecpan households showed a profit after accounting for the cost of family labor at the prevailing wage; substantially lower than Nauzontla's 73 percent (Inzunza 1988). If we deduct family labor, the value of *milpa*[11] covered only 65 percent of expenses incurred by Zoatecpan households, compared to 77 percent found in Naupan at the onset of NAFTA (Evangelista 1998).[12]

The persistence of a bankrupt maize sector in rain-fed regions suggests the market price for maize does not reflect the activity's worth to farmers. The difference between the market price of maize and the value of maize agriculture to farmers (its *shadow value*) must be attributed to the non-market goods and services the maize provides those who grow it: risk insurance and employment for family members, notably. Maize's value can also derive from culture. Maize has been at the center of village life for thousands of years, and its cultivation has cultural significance for many in Mexico. Researchers tend to believe that tradition and work-related satisfaction provide a major motivation for subsistence farmers who continue to grow maize despite financial losses (see e.g., Evangelista 1998; Perales 1998; Dyer 2002). Losses should be interpreted as the price paid for these benefits. Doing so allows us to advance research on farmer management of crop diversity from its current focus on *constraints* on production to include *choices* in consumption.

Dyer (2002) has studied the response of maize farmers in Central Mexico to several economic variables. He observes that even when the maize acreage remains constant within a community, individual farmers do respond to price changes. Total maize acreage does not drop with a price decrease because some farmers contract their maize operations while others expand it—a reaction that may seem abnormal from the perspective of production, but easily understood as a consumption choice. Farmers consume many of the goods and services that maize farming provides. Dyer concludes that farmers would grow more maize if their budget allowed them, which may readily be interpreted, from a production-constraint perspective, as lack of credit; but the possibility is undermined by the sector's lasting financial losses. A more parsimonious explanation is that it reflects a desire to grow maize for all its benefits, i.e., a consumption choice. Two conclusions come out from this research. First, the "apparent stability in [maize] production" is only apparent: statistics at the national level conceal the diverse ways in which farmers have responded to the liberalization process. Second, stability in maize

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[9] The opportunity costs of family land have been systematically, but unjustifiably, written off in these studies.
[10] *Milpa* is a multicrop activity based on maize, often in combination with beans, squash and other edible herbs.
[11] The value of *milpa* includes maize and beans.
[12] The average loss in Zoatecpan is only Mex$700 (*ca.* US$70) per household per agricultural cycle; twenty days work at the market wage.

production is not "the consequence of how poor producers respond under stress", but, largely, the consequence of farmers' choices and desires.

Differences in the way we interpret price responses are relevant to our discussion; they can change the forecast for *in situ* conservation. Nadal (2000) concludes from de Janvry et al.'s work that, "in spite of the drop in [maize] prices and the increase in imports, Mexico's production has remained stable—so far. But […] economic stress on the poorest producers will soon reach a threshold beyond which they cannot survive". De Janvry et al.'s (1995) theoretical proposition does in fact imply that while the status quo has been maintained, we can expect a downturn in production if prices continue to fall. Nadal concludes accordingly: "NAFTA presents a serious threat to Mexican growers' ability to conserve and develop [maize] genetic resources." Dyer and Taylor (2002) do a very different interpretation of the situation in the region of Mexico where Dyer (2002) described first hand responses to economic variables. They conceive farmers' decision to grow maize as an integral part of their economic life and lifestyle; then, they integrate the decisions of a large sample of local households to understand the region's economy. Dyer and Taylor conclude that the local maize sector has already restructured in response to NAFTA, but the maize surface is still unlikely to drop, despite further price decrease. Subsistence farmers will continue growing maize.

Economic decisions often seem unreasonable if out of proper context. Farmers' economic insertion cannot be properly described as a one-on-one response to abstract market signals; reaction to specific events, such as a price change, must be interpreted as part of farmers' integral economic life and in the context of their role in local economic activity. Rural families do not buy and sell in faceless markets; they trade goods and services with a variety of people in diverse circumstances. They may sell their labor in distant lands and buy food around the corner with neighbors. Rural families are diverse. Most of them buy and sell in markets; some also exert power over markets, hiring considerable land and labor and selling its product.

Dyer and Taylor suggest the series of events leading to the present in the Sierra Norte in Puebla. According to them, the reference price of maize, set by Diconsa in the early 1990s, gradually squeezed the profit out of the maize crop during that decade. As ill-financed commercial maize producers pulled out of agriculture, laying-off workers and renting the land out to big and small growers, some of whom were able to reap economies of scale in land and labor or transporting their maize to market. A few eventually stepped out of production and concentrated on buying and selling maize, taking advantage of different prices. Unemployed agricultural workers also rented in land, but to employ their unused time on-farm. Diconsa lost its grip on the market when private traders brought large enough quantities of maize, from surplus regions and the United States, at a lower price. At this stage, only the most competitive producers and a sizable group of subsistence maize growers continued to sow the land. In the end, maize output decreased slightly, even as the area in *milpa* remained constant: a result of reduced productivity, as land was taken up by less efficient farmers unwilling or unable to purchase fertilizers. Households now consume more maize—not only cheaper purchased maize but also homegrown maize. Along with the decline of commercial maize agriculture and the decrease in local market surpluses, greater consumption of maize has contributed to the village's deficit, which is filled with maize brought in from other regions. This is consistent with statistics at the national level, which show that Mexican maize imports soared during the 1990s even though maize acreage and domestic production did not drop as expected (INEGI 2001 and above).

In all, the liberalization of the maize sector brought about the decline of income and of commercial agriculture in this region. Despite land reform, it did not promote the expected consolidation of production into large competitive operations. Instead, it transformed the region's commercial maize agriculture into a largely subsistence sector, and it hurt local commerce: exactly opposite to forecasts (see Levy and van Wijnbergen). The government's cash-subsidy programs, Progresa and Procampo, helped support the wage-earning population, and in doing so, they sustained local expenditure and economic activity. The relative-price structure that resulted from the process of structural change favored the vertical integration of household production, allowing some of them to grow and feed small livestock later to be consumed at home.

Dyer and Taylor's account is generally consistent with Sadoulet *et al.*'s (2001) description of observed changes in household income among *ejidatarios* nationwide following NAFTA. This earlier analysis found that for the average *ejidatario*, the shares of wage, agricultural, and other off-farm income fell, while the shares of livestock, non-agricultural self-employment and migrant remittance income increased. However, Dyer and Taylor's description fits well only particular rain-fed regions where population density is high and landholdings small, which still includes many of those where landraces are grown. This is the case of the Gulf slopes of the Sierra Madre Oriental, where a sizable indigenous population still sows the land in maize. In other areas, such as the adjacent plateaus or the coastal range in Veracruz, small landholders still operate marginally profitable maize fields, selling their surplus in the Sierra through an elaborate network of middlemen (preliminary results of the National Survey of Rural Households in Mexico—ENHRUM). In other parts of the country, such as the State of Mexico where Conasupo used to purchase maize that fed Mexico City, rural population growth has slowly chipped away the surplus (ENHRUM, unpublished). In rural Morelos, where Diconsa is largely absent from the maize market, maize is bought and sold by neighbors in small *plazas*, isolated from larger markets. Still in other places, maize growers have rented out their land to agro industry, like in areas of Jalisco (M. Young, pers. comm.); or they have allowed second growth on fallow fields, as in the eastern lowlands of Chiapas (Dyer 2001) or in Guanajuato. Despite the variety of situations, it is clear that Mexican rain-fed-sector has not lain impassive to its liberalization, or in isolation. Yet, despite its restructuring, the maize surface has been maintained.

The restructuring of the maize sector in Puebla following NAFTA is of special interest, as this is the only place where its implications on maize diversity have been examined. Dyer (2002) integrated an *inclusive* model of crop diversity (see above) into Dyer and Taylor's (2002) community-wide framework to understand the connection between the maize sector's response to a price drop and *in situ* conservation of maize. The inclusive model (based on Meng 1997 and Van Dusen 2000) reveals an association between a diversity outcome (number of varieties) and household characteristics (schooling and number of agricultural plots). Projections for these variables, obtained from the community-wide model, are then used to predict the number of varieties per household for a wide sample of households. Not surprisingly, the exercise shows that conversion to subsistence agriculture is tied to an increase in *varietal* diversity; subsistence agriculture has been associated before with crop diversity (Brush 1986;

1992b). Increased diversity with conversion into subsistence agriculture would be expected since commercial producers tend to grow a single variety; but the referred effect on diversity in Puebla can be traced directly and exclusively to the redistribution of land among households—or more precisely, to the fragmentation of landholdings into small plots. That is, the increase in diversity was financed entirely by small farmers renting land to grow a little more maize.

Another expected consequence of NAFTA was widespread migration. It is worth noting that Van Dusen (2000) reports a negative association between international migration and varietal diversity in Puebla; but no significant association with domestic migration. An overwhelming majority of migrants in the region have domestic destinations (unpublished). Dyer (2002) found no evidence that domestic migration has an effect on diversity. Households in which migrants shuttle to work across Mexico largely avoided the economic slump that came along with liberalization. This could have given them greater access to land, but they did not seem particularly keen on agricultural production. Other studies have found that migrants may purchase land in their communities from afar (Massey *et al.* 1996). Their potential role in local land-use decisions raises other questions.

If the effect of structural change on varietal diversity in Puebla seems predictable, its effect on the crop's *genetic* diversity is still unclear. Dyer (2002) argues that measures of crop diversity must be sensitive to changes in the composition of the agricultural community, for these imply trade-offs between *varietal* and *genetic* diversity. The consolidation of agricultural land among fewer hands potentially allows households to grow more varieties; but its implications on varietal diversity at the community level depend on which varieties they grow (vis-à-vis other households). If the households remaining in agriculture have similar tastes or make similar choices, it is possible that the number of varieties present in a community will fall even when the number of varieties managed per household increases. Consolidation of land can also influence genetic diversity, through its effect on the size and number of *land plots* grown and, thus, on the size and number of *seed lots* managed (see Sanchez *et al.* 2000). Land consolidation reduces the possibility of genetic drift and preserves genetic diversity when diversity is mostly manifest *within* seed lots. When diversity is greater *across* seed lots, land consolidation promotes its loss. The question rests with population geneticists; it must be solved before sensible *in situ* conservation programs can be implemented.

As mentioned earlier, Dyer (2002) described maize *in situ* conservation in a mountainous region characterized by rain-fed agriculture and high population density. What do we know of *in situ* conservation in other regions of Mexico? The positive outlook for *in situ* conservation announced by some is based not only on the analysis of household decisions, but also on the apparent abundance of landraces across the landscape (Table 2). Despite impressions, there is no information on the recent evolution of maize diversity. Few studies have assessed diversity repeatedly in a single location. Bellon and Risopolous (2001) recently revisited the *ejido* Vicente Guerrero, Chiapas, originally studied by Bellon and Taylor (1993), and found that the number of varieties managed (by a comparable sample of farmers) had increase from 15 to more than 20. Like the work of Hernández and Ortega (1973) thirty years earlier, this finding appears to suggest that maize diversity has increased in the region, but a complete assessment of diversity requires, in addition to a landrace count, an account of landrace abundance and its distribution among households (Brush *et al.* 1988; Meng *et al.* 1998a). Changes in the abundance and frequency of landraces can have a profound influence on their genetic composition (Sanchez *et al.* 2000).

Data on the distribution of landraces across households has not been reported systematically. Its importance is illustrated using available statistics for Puebla. In its region of Sierra Norte (SNP), the number of maize varieties has remained constant for at least 10 years (Table 2, column b), but the average number of varieties per household dropped from 1.3 in 1988 to 1.1 in 1999 (column d). This modest change can come about, for instance, if the number of households holding two varieties (i.e., instead of one) drops from 3 in 10 to 1 in 10. This is a striking change from just over ten years ago, considering most households now grow the same maize variety. It suggests that maize diversity in Puebla may be in peril for reasons other than market integration (see Dyer 2002).

The issue of an integrated North American maize market and its effect on maize conservation is not solved, but it has already had a considerable influence on the debate on *in situ* conservation. It has brought Mexican maize diversity to the media's attention (Enciso and Castellanos 2002; Nadal 2002), helping raise public awareness of the need to conserve these resources. It has also widened the scope of research on *in situ* conservation, leaving behind the emphasis of years past on landrace displacement. Yet, there is still in this research a consistent pattern of preoccupation with the effects of trade, exchange and commercialization—from the spread of Green Revolution technologies, to the commercialization of traditional agriculture, to the integration of markets. However, these threats have rarely materialized and they have generally dissipated without *in situ* conservation ever being implemented. Researchers addressing *in situ* conservation have always focused on farmer decisions: first, it was their production decisions under constraint, and more recently, their consumption choices. For all we know, it is these choices that have conserved CGR *in situ* in the absence of public involvement. However, in the past few years, concern for the spread of technology and the exchange of goods has converged in a preoccupation with the flow of genes—and it is not yet clear how this potential threat resembles those of the past or how farmer decisions come into place.

3.4 The spread of transgenes

In 1994, NAFTA opened the door to the free flow of maize seed across North America. Since then, the door has been set ajar in an effort to prevent the release of transgenic maize into the Mexican landscape (Hodgson 2002). The eventual arrival of transgenic maize in Mexico—maize's center of diversity—has concerned scientists for years (see Serratos *et al.* 1995); but it was not until Quist and Chapela (2001) reported the presence of transgenic constructs in Oaxacan landraces that it became a national concern (Enciso 2002; Hodgson 2002; Zarembo 2002; Carpentier and Hermmann 2003). Mexican experts testifying in Senate hearings have expressed their concerns with the possibility that transgenic maize will *displace* landraces and increase farmer dependency on corporations (Enciso 2002); but the overriding public concern is that transgenes will "contaminate" Mexican landraces. The scientific community, both in Mexico and abroad, still debates a variety of questions on the possible spread of transgenes, including the veracity of the claim and its possible consequences: the appearance of weeds, resistant pests or resistance to antibiotics, and the genomic instability in maize (see e.g., Ellstrand, 2001; Alvarez-Buylla 2003).

Part of the debate on the environmental effects of transgenic crops centers on the distinction—or lack of it—between transgenic and non-transgenic crops (see e.g., Gepts 2002). There is a perception that transgenic crops are being subject to greater scrutiny than conventional varieties. A committee reporting to the U.S. National Research Council (NRC) examined the basis for this comparison and concluded the more rigorous standards for transgenic crops are partly justified by greater public concern for the environment today. It also concluded "the transgenic process presents no new categories of risk compared to conventional methods of crop improvement." Significantly, the committee's charter precludes consideration of environmental effects outside the United States, which excludes potential effects in centers of crop diversity such as Mexico.

From an *in situ* conservation perspective, the spread of transgenes to maize landraces represents an entirely new type of threat. Previous threats to *in situ* conservation were confined to one of two types: landrace displacement or crop replacement. Gene flow between non-transgenic maize varieties has generally been considered advantageous (see e.g., Bellon and Risopoulous 2001; Bellon *et al.* 2003). Whether the risks involved in the spread of transgenes are in a new category or not, as suggested by the NRC, the novelty of this potential threat finds us unprepared to deal with it. Evidence to this effect is the fact that there is still no clear indication of what the source of those transgenes might be, but only anecdotal reports in the press (Zarembo 2002). There are two basic vehicles for transgenic dispersal: grain/seed and pollen. The long-distance transport of grain and seed is the easiest way of introducing transgenes in any country or region. If seed or grain containing transgenic material is then grown locally, pollen may become an additional vector for transgenes. After transgenic material becomes established in local maize populations, secondary dispersal will occur through poorly known seed networks and staple markets (Louette and Smale 1996; Rice *et al*. 1998; Perales 1998; Dyer and Taylor 2002). In short, "the same conditions […] that promoted and maintained maize diversity in Mexico [are] conducive to the diffusion of transgenes (Bellon and Berthaud, n.d.)". Whether or not transgenes reported in Oaxaca are an environmental threat, it is vital that we take this opportunity to investigate the mechanisms of their escape and dispersal.

We cannot rule out that transgenes escaped from field trials conducted until recently (but see CIMMYT 2001), but the greatest possible source of transgenic material in Mexico is maize imported from the United States.[13] Labeling of transgenic maize is not required in the United States, so a third of maize exports to Mexico is in all likelihood transgenic (Rousu and Huffman 2001; Sheldon 2002). Transnational migrants have also contributed to the dispersal of transgenic seed, but reports suggest this practice could not explain the apparent extent of transgenes reported by Mexico's National Institute of Ecology (*Instituto Nacional de Ecología*—INE 2002). We've presumed transgenic maize was introduced to Oaxaca through Diconsa (Quist and Chapela 2001); in fact, since Conasupo was dismantled, an unknown number of private merchants distributes

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[13] M. Bellon (CIMMYT, pers. comm.) suggests transgenic maize pollen could float across the border from Texas into Tamaulipas due to close proximity of maize fields on both sides of the border.

U.S. maize across Mexico. This trade network will eventually help disperse transgenes after their introgression into Mexican landraces.

4.0 Prospects and recommendations

There is yet no indication that increasing maize imports under NAFTA have resulted in the abandonment of subsistence maize agriculture in Mexico. Lack of evidence is typically not useful in making decisions, but research suggests relative prices might have helped convert commercial maize agriculture into a subsistence practice in some regions, increasing local maize diversity.[14] Many questions remain unanswered, especially in other parts of Mexico; but this finding should reduce concerns raised by the Commission for Environmental Cooperation's previous environmental assessment of NAFTA (CEC 1999). Also associated to maize from the United States, the spread of maize transgenes to this crop's center of diversity in Mexico is now at the forefront of the debate. The spread of maize transgenes and its environmental implications are still highly disputed issues that have raised the need for *in situ* conservation.

Costs are a fundamental aspect of CGRs conservation. *In situ* conservation was considered economically infeasible for many years, making research superfluous. We still assume that *in situ* conservation implies permanently subsidizing traditional agriculture, although there is no clear association between development and loss of crop diversity. The cost of conserving landraces depends on the efficiency of a conservation strategy, which in turn is contingent upon the research to support it. Efficiency can be achieved by addressing specific threats to conservation individually. This will allow limited but specific responses to threats. Recent scrutiny of long standing threats to Mexican landraces has dispelled those threats without the need for an active conservation program. For instance, Perales (1998) found that MVs grown in the states of Mexico and Morelos would not out compete local landraces, which undermines concerns with landrace displacement in these places. Similarly, our work in Puebla speaks against the need to act in this region.

Despite encouraging results, there is substantial need for stepping up efforts for conservation. It is fundamental to establish a monitoring and research program that will enable us to detect and respond to contingencies. A well-funded monitoring and research program is the soundest way to reduce the costs of CGR conservation *in situ*. Areas in need of research are cultural change and loss of indigenous values. Also of concern are changes in land tenure following the reform of Article 27 of the Mexican Constitution. A monitoring program must be designed to detect long-term processes—such as cultural change, land consolidation and rural out-migration—but also more rapid developments such as the spread of transgenes. Ongoing work in the states of Oaxaca and Chiapas holds promise (Perales pers. comm.; Bellon *et al.* 2003; Smale *et al.* 2003), but this is not extensive to the rest of the country. A monitoring program must comprise representative locations around the country and register changes in the frequency and abundance of landrace cultivation, as well as basic socioeconomic variables: farmer profile and product destiny. A first step towards installing such a program will be the definition of a standard sampling methodology (see Dyer 2002). To this end, it will be necessary to define different study units (i.e., genes, varieties, households, communities), which will require

[14] Maize diversity is defined here as the number of varieties per household.

the collaboration of specialists in various disciplines. Once in place, a monitoring system will alert us of changes in the status quo of landrace management, which is only a first step in detecting potential threats to conservation. The varied nature of conceivable contingencies requires that the flow of data generated by this system also be interpreted by a diverse group of specialists. All of this requires institutional capacity and funding.

The Mexican government has been slow in fulfilling its commitment to the preservation of landraces and traditional knowledge. We are not aware of any effort by a government agency to promote *in situ* conservation. Alternatively, research institutions have taken up this task. The joint Conacyt-Semarnat Fund for Environmental Research has received applications for two projects on crop *in situ* conservation and three more on the spread of transgenes (Conacyt 2003). Funding is pending, but research institutions have already started addressing public concerns. The National Survey of Rural Households in Mexico—ENHRUM—has taken the lead gathering countrywide information on the life and house-economy of families living across the countryside this year.[15] This includes extensive information on local and regional maize markets. ENHRUM also collected a wealth of information on the management of maize in rural homes, which includes—for the first time ever—data on the extent of maize seed networks across the nation. Finally, in association with researchers in the University of California and El Colegio de la Frontera Sur, ENHRUM collected a nationally representative maize sample. All of this will help answer the unsolved questions we have addressed in this paper.

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[15] ENHRUM is a joint program of PRECESAM (El Colegio de México) and REAP (University of California).

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Table 1 Decomposition of the domestic price of maize: 1977-2000 (simple average percent changes)

Period	Real domestic price	Real International price	Real Exchange Rate	Residual
(77-82)-(83-90)	-6	-41	25	10
(83-90)-(91-93)	-24	21	-20	-25
(93-94)-(95-96)	8	-40	39	9
(95-96)-(97-00)	-40	-37	-33	30
(91-93)-(94-00)	-35	-49	5	10

Source: Yunez-Naude, A. and F. Barceinas: Dec. 2002.

Table 2 Number of maize varieties in communities across Mexico.

	(a) total number of varieties[1]	(b) number of landraces[1]	(c) number of local landraces	(d) number of varieties per household[1]	(e) (a)/(d)[1]
Sierra Santa Marta (Rice *et al*., 1998)	30	24	-	5.8	5.2
Cuzalapa (Louette & Smale, 1996)	26	21	6	2.4 + 2.6	5.2
Guanajuato (Aguirre *et al.*, 2000)	23-16		-	-	-
Ocozocoautla (Brush *et al.*, 1988)	14		-	2.7 (1-5)	5.2
V. Guerrero (Bellon & Taylor, 1993)	15		-	-	-
V. Guerrero (Bellon & Risop., 2001)	20+	11+	-	-	-
Chalco-Amecameca (Perales, 1998)	8 (3-7)	7 (3-6)	-	1.6 (1-4)	5
Valley of Cuautla (Perales, 1998)	17 (4-13)	13 (0-10)	-	1.4-1.8 (1-4)	9.4-12.1
Naupan, SNP (Evangelista, 1998)	6	6	-	-	-
Nauzontla, SNP (Inzunza, 1988)	6	6	6	1.3	4.6
Sierra Zacapoaxtla, SNP (VanDusen, 2000)	-	-	-	1.1	-
Zoatecpan, SNP (this study)	-	-	-	1.75	-
Oaxaca (Bellon, 2001)	11?	-	-	1.6 (?-2.1)	6.9?

1. Range in parenthesis.
Source: Dyer (2002).

Figure 1. Maize, Imports and Domestic Production: 1983-2000 (annual averages)

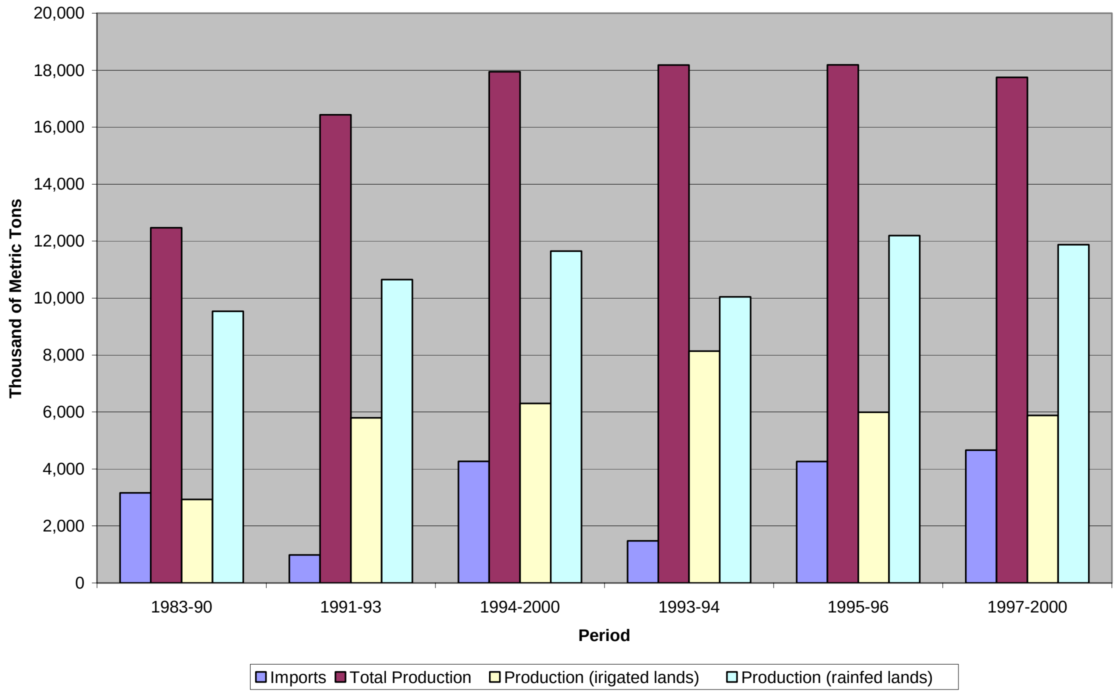

Figure 2. Maize, Cultivated Area: 1983-2000 (annual averages)

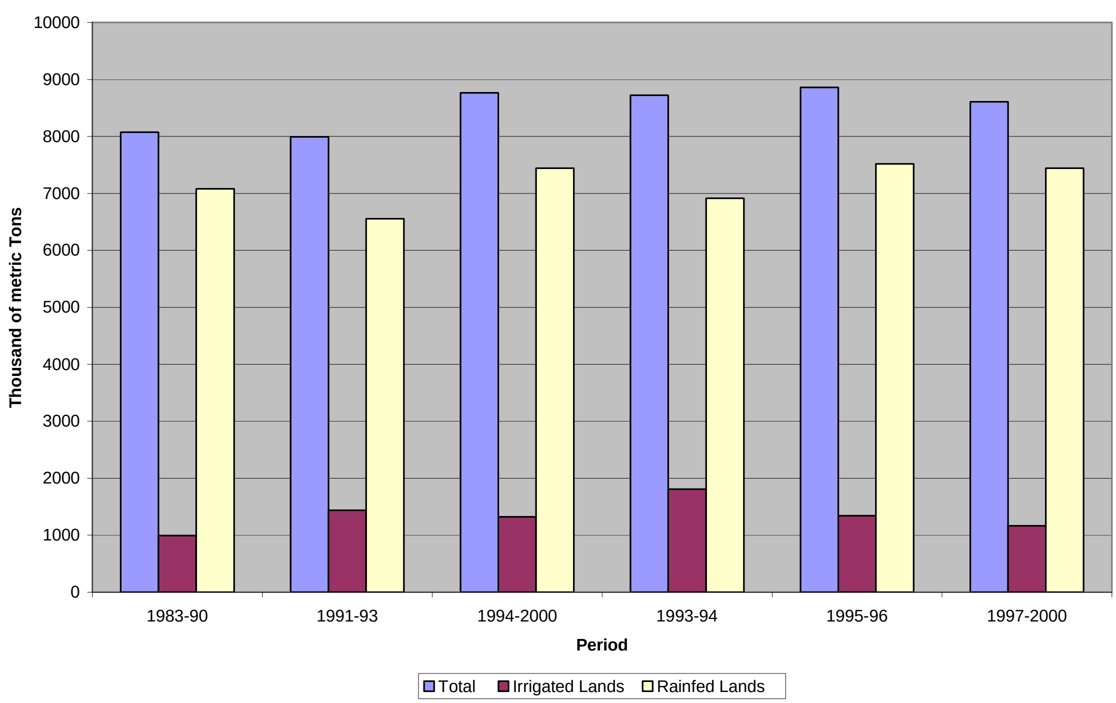

Figure 3. Maize. Yields: 1983-2000 (annual averages)

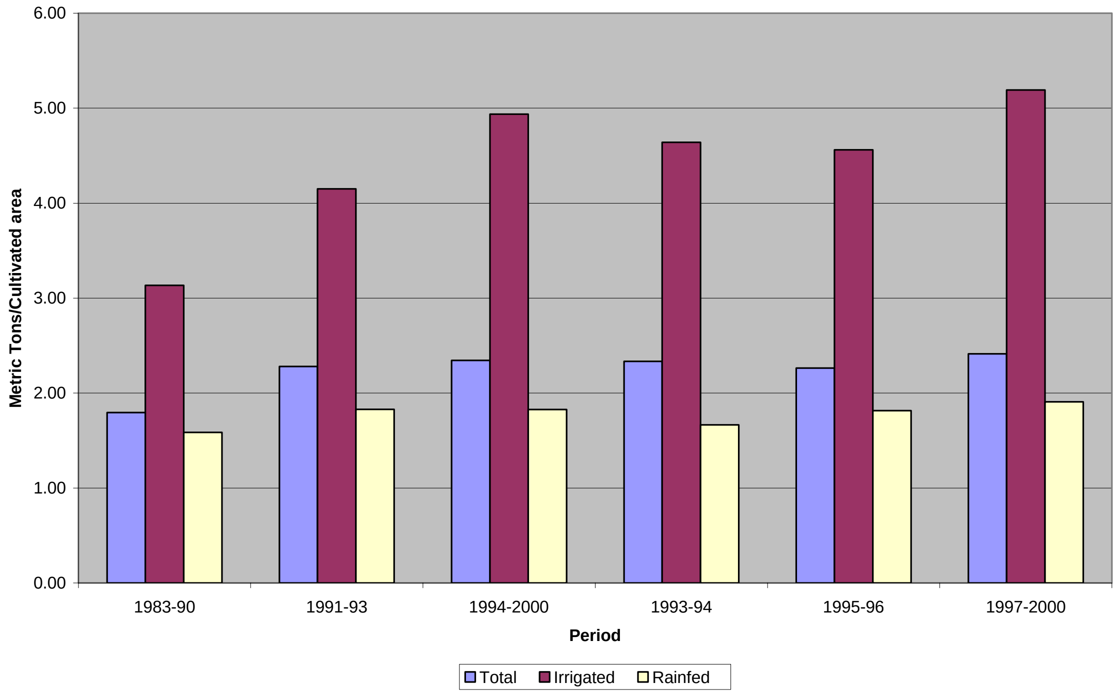

Figure 4. Maize Imports: 1991-2000