Maize and Biodiversity: The Effects of Transgenic Maize in Mexico

Chapter 6

Assessment of Social and Cultural Effects Associated with Transgenic Maize Production

for the Article 13 Initative on
Maize and Biodiversity

Prepared by Stephen Brush and Michelle Chauvet

Advisory Group Reviewers:
Julian Kinderlerer (lead), Mindahi Bastida Muñoz, Peter Phillips, José Sarukhán and José Luis Solleiro

External Reviewers:
Kirsten Appendini, Rafael Ortega Paczka and Garrison Wilkes

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I. Introduction

The objective of the chapter is to assess potential social and cultural effects of transgenic maize on Mexican farmers. Assessing the impact of technological change is never a precise science, and in this case, it is complicated by the highly differentiated agroecological and social rural contexts of Mexico. In the first part, we present an overview of Mexico's agriculture emphasizing its heterogeneity and different types of farms that produce maize. The second part is focused on the potential effects of transgenic maize. The methodology followed is to review the changing nature of maize agriculture in Mexico and the impact of other types of technological change on different types of farms and on maize diversity. The chapter then reviews potential impacts of transgenic maize on farmers' choice and rights, on yield and income, and on cultural values. Three groups of farmers are considered – non commercial, semi-commercial and commercial producers.

I.A. Assessing social and cultural impacts of new technology in agriculture

Social impacts are defined broadly as "the consequences to human populations of any public or private actions," and social impact assessment (SIA) is defined as "efforts to assess or estimate, <u>in</u> <u>advance</u>, the social consequences that are likely to follow specific policy actions and specific government actions…" (Interorganizational Committee 1995) The action in question here is the sanctioning and planting of maize that has been transformed by the insertion of genes and gene sequences from outside of the crop's primary gene pool, the customary source of breeding material. The impacts in question result from changes in agricultural practices, consumption, and markets that might arise because of the introduction of transgenic maize into Mexico. On one side, negative impacts might include declines in income or the availability of food, loss of relative economic or social position, and loss of agricultural assets that are part of cultural identity. On the other side, positive impacts associated with the presently available transgenic maize (with Bt and herbicide tolerance traits) might include reduced costs, health effects, and environmental damage from aerial insecticide spraying and reduced labor costs for weed control.

While the cultural importance of maize to Mexico is discussed in this chapter, its emphasis is on social impacts. The reasons for this emphasis are the lack of standard definitions, units of measurement, and methodology in social science for predicting cultural impact and the lack of information about how transgenic maize is expected to affect different maize populations and characteristics of maize apart from the expression of the specific transgenic trait. Unlike social impact assessment, cultural impact assessment lacks a consistent and accepted set of factors that can be measured for the effect of new technology. Social impact assessment reports regularly on the impact of new technology on specific social groups and categories, such as small-scale farmers, economic class, gender, educational background, ethnicity, as well as on community functions, such as civic participation. Cultural studies start from the assumptions that every culture is distinct and that no standard measurement is appropriate across cultures. The consequence for studying impact of technology is that every culture should be assessed independently. Mexico is well known as a society with numerous cultures. While several studies point out the importance of maize to specific cultures (e.g., Sanderson 1981, González 2001), no study has formally assessed the impact of new maize varieties and technology on the cultural meanings of maize. Moreover, current theories of culture strongly emphasize the fact that culture is a set of symbols and a knowledge system that is constantly changing and permeable to symbols and knowledge from other cultures. While numerous ways of preparing, consuming, and otherwise using maize are known in Mexico, information is lacking on how transgenic traits, such as Bt expressed in leaves and roots or herbicide tolerance, will affect preparation and use of the grain. Likewise, this chapter documents that maize populations are open systems in Mexico and that new traits are commonly sought after and established in local maize populations. No study to date has related this practice to cultural perception and impact, so that assessing the cultural effect of transgenic traits will be highly speculative.

Although the initial emphasis of SIA researchers was on quantitative assessment of future impacts, practitioners now accept the idea that SIA is a qualitative process whose purpose is to promote public involvement around issues of technological change and to identify the types of social impacts that are likely to be important. A recent compilation (Vanclay 2002) of categories and types of social impact lists seven general categories (e.g., health and social well-being, quality of living environment, and economic and material well-being), and 78 specific types of impact among the general categories. Many of the social impact categories, such as quality of life, are ambiguous and defined in different ways (e.g. Diener and Suh 1997). The sheer number of possible impacts, the complexity of defining and measuring impacts, the possible roles of many causal variables to any one effect, and the lack of bench-mark data frustrated the goal of determining impact in a quantitative fashion. The number of explanatory variables for a social effect often is greater than the number of cases available to assess impact of a single factor (Meidinger and Schnaiberg 1980). The result of these methodological problems has been to turn SIA toward qualitative approaches that emphasize public involvement in identifying important impacts and information gathering about those impacts (Burdge and Robertson 1990).

SIA is usually associated with technologies and projects that have clear social and geographic identity, such as roads, dams, pipelines, and power plants. This type of project allows the SIA analyst to limit the investigation to social groups and locations where impact is likely to be felt. While some agricultural technologies and projects, such as an irrigation project, are limited in geographic and social context, most agricultural technology is relatively broad and unbounded in terms of its potential impact. These characteristics multiply the difficulty in defining impacts and determining causation, and they increase the likelihood that a technology may be positive for one sector or region and negative for another. The introduction of transgenic maize into Mexico typifies a technology whose impact will not be confined to a specific social group or geographic region. Because of the importance of maize in Mexico, introduction of transgenic maize there will have effects across different social sectors and geographic regions –

commercial and non-commercial farms, rural and urban consumers, indigenous and non-indigenous communities.

While technological change has both positive and negative effects, impact assessment has traditionally emphasized the anticipation of negative effects of new technologies (Finsterbusch 1980, Lacy 2001). The evaluation of technological change in agriculture has focused on two broad categories of negative impacts: (1) a bias in the technology that favors specific types of farms (e.g., large vs. small farms) (e.g., Griffin 1974, Qaim 1998), social groups (e.g., male vs. female farmers) (e.g., Gloverman and van Wilsum 1994), and regions (e.g., lowlands vs. highlands) (e.g., Brush et al. 1988), and (2) a decline in the quality of life of rural communities (e.g., Goldschmidt 1978). These two categories of effect have been extensively researched for specific farming systems and technologies. For instance, the issue of bias in new agricultural technology has received attention in Asian rice systems affected by the Green Revolution. Contrasting evaluations have been presented over time by Palmer (1976), Karim (1986), and Evenson and Gollin (2003). The issue of declining quality of life has been studied in the U.S. since Goldschmidt's (1978) landmark study that associated an inferior quality of community with large farms. Other social scientist have related Goldschmidt's finding to the long term restructuring of the rural sector toward larger farms and the role of technological change in driving this trend. The key analysis of rural restructuring is Cochrane's (1993) of the "technological treadmill" in which acquisition of technology is part of inter-farm economic competition. Luloff and Swanson (1990) provide comparative analyses of the social impact of declining numbers of farmers and increasing farm size in different regions in the U.S.

The evaluation of bias and declining quality of life relating to technological change in agriculture has generated contrasting studies that find evidence of negative and positive social impacts of the same technology. Technological bias has been extensively studied in relation to the diffusion of high yielding rice varieties in Asia during the Green Revolution. Frankel (1971) and Griffin (1974) provide negative assessments citing scale bias, while Hazell and Ramasay (1991) and Hayami and Kikuchi (2000) find no scale bias and give positive assessments. Labao et al. (1993) dispute Goldschmidt's assertion that increasing farm size causes negative impacts on the quality of life in rural towns. One conclusion from the comparative studies of negative social impact of specific agricultural technologies is that it is all but impossible to confirm cause-and-effect relationships between specific technologies and social conditions. While the potential for negative impacts is present, there is often insufficient evidence about the significance of the impacts, how they weigh against positive impacts, and whether technological change is the most important causal factor. All of these issues are present in assessing the social impact of transgenic maize in Mexico.

I.B. Social groups and the social structure of Mexican maize agriculture

I.B.1. Structural factors

Agricultural activities in Mexico are important not only from the economic but also from the social and cultural point of view[1]. The sector's contribution to the Gross Domestic Product for 2003 was 6% in comparison with industrial and service activities that represented 27.1% and 67%, respectively (INEGI 2003a)[2]. The economically active population comprises 16.4%, that is, 6,813,644 persons (INEGI 2003b). Of the total population of the country, 101,842,400 inhabitants (Population Reference Bureau 2004), 25.2% belong to the rural population. The state of Oaxaca has the largest percentage of rural inhabitants (INEGI 2000).[3]

Maize is the most important crop in Mexico in terms of area sown, production value and personnel employed, and it is also the staple food of the Mexican population. Indeed, in 2002, 59% of the agricultural land was planted with maize, which generated 21% of total agricultural production value (III Informe de Gobierno 2003). With respect to manpower employed, it is difficult to obtain recent data, but in the mid-nineteen nineties, between 35% and 40% of the agricultural labor force was occupied in the cultivation of this grain. (Fritscher 1999). Because of its contribution to the social and cultural identity of Mexico, maize agriculture in Mexico is relevant beyond its economic importance.

Maize types vary according to whether it is produced as food grain, forage, or for industrial purposes; and food grain is of primary importance. Over the last decade, the area of national production has been stable, with 8 million hectares, with a slight tendency to increase in the last few years. In 2002, rain fed cultivation accounted for 63% of the maize area with average yields between 1.2 and 2.6 t/ha. Yields of irrigated maize, in contrast, averages 4.5 t/ha with yields reaching 8 and 12 t/ha.

From one perspective, the rain fed sector is inefficient and backward (Barkin 2003).[4] However, "efficiency" is a relative concept, and practices that are thought to be inappropriate in one sector are rational in another. Nevertheless, the social and cultural significance of rain fed maize contributes to its persistence in Mexican agriculture despite its low economic returns. Maize is cultivated in virtually every state of Mexico, in a Spring/Summer cycle and a Fall/Winter one. The distribution of areas in these cycles is

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[1] The quantitative foundation for this fact is limited because the VIII Agricultural Census that should have been taken is missing. Because the dates from the 1991 census do not reflect the current situation, more recent sources were used although they do not have the same breakdown as the census.

[2] In 2003, the sector contributed 83,452 million pesos to GDP (at 1993 prices) (III Informe de Gobierno. 2003 with data from INEGI Sistema de Cuentas Nacionales).

[3] The percentage of rural population is tending to decrease, in 1990 it was 28.7%, in 1995 26.5% (INEGI 1990; INEGI 1995). Projections for 2003 are a total population of 104.2 million inhabitants, with the percentage of rural population remaining the same (III Informe de Gobierno 2003)

[4] In spite of the lack of competitiveness of Mexican maize with respect to the United States and Canada, this crop was included in NAFTA, the objective of the Mexican government was to force conversion of crops to more competitive products (de Ita 2000; Dyer and Yunez 2003).

shown in Table 6.1. The Spring/Summer cycle is the period of rain fed agriculture.[5] In the 1990s, five states were the primary producers of maize – Sinaloa, Jalisco, México, Chiapas, Michoacán, and Puebla – providing 55% of the national production. Among these states, Jalisco is the leader in Spring/Summer production and Sinaloa leads in Fall/Winter, irrigated production (ACERCA 1997).

Table 6. 1

Area and Production of Maize in Mexico[1]

Year	Area cultivated (hectares)			Production (tons)		
	Total	Rainfed[2]	Irrigated[3]	Total	Rainfed	Irrigated
1993	8 249 761	6 529 120	1 720 641	18 132 163	10 421 635	7 710 528
1994	9 196 743	7 299 430	1 897 313	18 236 496	9 660 437	8 576 059
1995	9 081 876	7 622 719	1 459 157	18 359 145	12 070 222	6 288 923
1996	8 639 182	7 409 744	1 229 438	18 026 553	12 314 809	5 711 744
1997	9 133 250	7 748 893	1 384 357	17 657 055	10 733 876	6 923 179
1998	8 521 684	7 295 588	1 226 095	18 458 147	12 350 698	6 107 448
1999	8 496 493	7 466 797	1 029 696	17 708 162	12 641 544	5 066 618
2000	8 446 102	7 384 679	1 061 422	17 559 776	11 820 777	5 738 998
2001	8 396 979	7 328 313	1 068 666	20 134 723	13 869 184	6 265 538
2002	8 271 817	7 096 891	1 174 925	19 299 234	12 241 341	7 057 893

1 Includes white and yellow maize grain, seed and popcorn
2 Rainfed agriculture is the Spring/Summer cycle
3 Irrigated agriculture is the Fall/Winter cycle
Source: SAGARPA 2003.

[5] In 1991, maize cultivation occupied 2.4 million producers during the spring-summer cycle, 82% of whom were concentrated in ten states: Oaxaca, Guerrero, Hidalgo, Michoacán, Chiapas, Jalisco, Estado de México, Puebla, Veracruz and Guanajuato (SARH 1992 cited in de Ita 2000).

Polarization and large disparities in the configuration of cultural, socio-economic, and technological elements characterize contemporary Mexican agriculture (Sanderson 1981, Hewitt de Alcántara 1994, Nadal 2000). Maize production across different regions and social groups shows the contrast between industrialized production using advanced technology and commercial hybrid seed (e.g., Aguirre G. 1998) and subsistence production relying on elements of pre-Hispanic technology and traditional landraces in shifting cultivation (e.g., Nations and Nigh 1980). Despite these contrasts, however, all maize systems in Mexico are based on combinations of local and non-local and older and newer elements. Maize production varies across ecological regions, cultures, and socio-economic groups and an infinite number of different combinations and forms of production are possible. However, social impact assessment requires that this complexity be reduced to well defined types of producers. Numerous studies of the social aspects of agriculture in Mexico and elsewhere emphasize farm size, use of from production, and use of off-farm inputs as key criteria is deciding how to assess social impact of new technology and policy. One way to reduce the complexity of the many different regions, cultures, and social groups that produce maize is it to distinguish between non-commercial, semi-commercial, and commercial producers. These categories are roughly equivalent to “traditional,” “subsistence,” and “entrepreneurial” used in Chapters 1 and 3, but they avoid the ambiguity of the concept “traditional” which is problematic because of the diffusion of new technology and other changes that affect all farm sectors in Mexico. These three categories are found across different maize producing regions and differ according to farm size, the production objective, source of maize seed, use of purchased inputs such as fertilizer and pesticides, and access to irrigation.

Table 6.2 Farm types in Mexico

Category	Non-commercial <2 hectares	Semi-commercial 2–5 hectares	Small commercial 5–20 hectares	Large commercial >20 hectares
Number of farms[a]	1,305,345	958,338	1,193,865	365,515
Percent of total farms (1991)[a]	34	25	31	10
Percent of total farm area[a]	01.6	03.8	13.8	79.2
Average farm size[a] (ha)	01.1	03.6	10.6	202.1
Production Objective	Home consumption and limited market	Home/Market consumption and market	Market	Market
Seed Supply system	Local and informal	Local and informal	Informal and formal	Informal and formal
Purchased input use	Limited	Limited	Moderated to high	Moderate to high
Irrigation	Limited	Limited	Moderate to	Moderate to

access			high	high

[a]INEGI 1991

The non-commercial and semi-commercial sectors comprise 60% of the farm units, utilize 33% of the maize area, and produce 37% of the national production of the grain (Nadal 2000). The data on the commercial sector in Table 6.2 conceals the fact that a small percent of very large farms control a disproportionate amount of the agricultural and forestry land. C. de Grammont (2003) finds that firms controlling more than 1000 hectares represent 0.3 percent of the total production units but control 45.6 percent of Mexico's total agricultural and managed-forest land. Farms in the commercial sector that control 5–20 hectares comprise 31 percent of the total number of production units, control 13.8 percent of the farm area and average 10.6 hectares (C. de Gammont 2003). In other words, the non-commercial, semi-commercial and small-commercial (farms 5–20 hectares) account for 90% of the total production units but control 19.2 percent of the production area in the agricultural Mexican sector.

As the priority in the non-commercial and semi-commercial sectors is supplying food for the family, the quality criterion is equally important to productivity. In fact, the value of the production unit cannot be solely measured with financial criteria, but also requires consideration of social and cultural values relating to consumption. In many regions, especially in southern Mexico and in the highlands of the Sierra Madre Occidental, maize cultivation is associated with beans and squash, as well as with the use of some edible greens that grow beside them. This practice is known by the name of *milpa* (Aguilar et al. 2003, FIRA 1998). The practice of intercropping has descended from pre-Columbian agriculture and creates a system that produces not only calories from the basic grain but also vegetable protein and the base of condiments that are central to Mexican cuisine.

According to a survey[6] carried out in 1991 during the Spring/Summer cycle, maize producers divide into two large groups depending on farm size. One group, with farm sizes less than five hectares, represents 92% of all producers, occupied 67% of the maize area, and produced 56.4% of all production. Fifty-two percent of this production was for home consumption. Yields varied between 1.3 and 1.8 t/ha. The second group, with farms larger than five hectares, produces 43.5% of the national production, and only 13.6% of this group's is destined for home consumption. Yields for these farms varied between 1.8 and 3.2 t/ha (de Ita 2000).

Table 6.3 summarizes data from a survey showing that maize producers with less than one hectare and no more than two, dedicated more than 80% of their production to home consumption, while those with two to five hectares sold 60% of their production. The 1990s were a decade of profound changes in the countryside because of the impact of policy changes and market liberalization. Small commercial farms that were viable under the former subsidized maize system have turned to subsistence and off-farm employment to supplement lost farm income. Although census data is missing, fieldwork suggests that

[6] SARH-DGE 1991 Encuesta Nacional de Costos, Coeficientes Técnicos y Rendimientos de la Producción Agrícola. México, cited by Fritscher 1999; de Ita 2000.

this situation persists in 2003, with small producers consuming most of their production and supplementing this with purchased maize.[7]

Table 6.3

Production and Sale of Maize by Farm Size
(Metric Tons)

Farm size	Producers %	Production[1]		Sales[1]	
		Tons ('000)	%	Tons ('000)	%
0–1	39.7	1 161	10.4	209.0	18
1–2	26.9	1 520	13.6	574.6	37.8
2–5	25.5	3 630	32.5	2 276.0	62.7
5–10	6.20	2 511	22.5	2 089.0	83.2
10–20	1.3	1 341	12.0	1 174.7	87.6
> 20	0.4	1 011	9.0	963.5	95.3
All farms	100	11 174	100	7 287.0	65.2

Source: SARH-DGE 1991 Encuesta Nacional de Costos, Coeficientes Técnicos y Rendimientos de la Producción Agrícola. México (Fristcher, M. 1999)

Households in each of the categories in Table 6.2 both sell and purchase maize. Smaller units, which are found in the non-commercial sector, are often "sub-family" farms in the sense that although they are oriented toward producing for home consumption, their production is not sufficient to meet household needs. Dyer L. (2002) notes that 94% of the households in his study region in the Sierra Norte de Puebla produce less than their yearly consumption of maize, and 67% produce less than 25% of their maize consumption. In a study in five communities in the Sierra Norte of Oaxaca, Appendini et al. (2001) found that household production accounted for 66% of the local consumption. The pattern of lack of self sufficiency extends to Mexico as a nation. In 2002, Mexico produced 78% (19.3 million tons) of its total maize consumption and imported 22% (5.4 million tons) (SARGAPA 2003).

With the use of chemical inputs and the availability of improved seed, some maize production in the states of Jalisco, México, Puebla, and Michoacán since the 1970s has been done in monoculture in contrast to other areas where intercropping continues. Nadal (2000) calculates that farms averaging 2.4 ha and larger have profits, although it is not

[7] In interviews with small maize producers in Michoacán, Jalisco and Colima during 2002 and 2003, they mentioned that they can no longer exchange their "criollo" maize for products in stores or sell it to the millers or tortilla producers as they no longer receive them. Other fieldwork results in different geographic regions show a similar pattern (Bellon 1990, Perales R. 1998, Dyer 2002).

clear whether hidden costs, such as the value of family labor or land, are included in these calculations.

Large commercial producers, located primarily in Sinaloa, Jalisco, and Guanajuato, practice a form of industrial agriculture with intensive use of capital, chemical inputs, certified seed, and mechanization. Large farms are cultivated under irrigation in the Fall/Winter cycle. In the case of Sinaloa, a primary problem is distance from the main population centers and the cost of transportation. In order to facilitate competitiveness with other regions and imported maize, the Mexican government in 1996 established a program to support the commercialization of Sinaloan maize. This subsidy represents a significant portion of the value of production and farmer income, but it is a regressive subsidy that benefits only commercial maize of the Fall/Winter cycle (de Ita 2003).

Mexican maize production is allocated into four different uses: 57% goes to human consumption, 26% for animal production, 11% for starch, 2% for seed, and 4% wastage (FIRA 1998). Mexico now imports approximately 25% of its annual maize consumption, although most of the imported maize is yellow and used for animal feed and industrial uses. Human consumption is primarily in the form of tortillas, elaborated from traditionally prepared meal (nixtamalizado) or industrially produced flour. The preparation of tortillas ranges from homemade, small commercial production, and industrialized production based on using maize flour. A great variety of tortillas exists, and there more than 600 different food preparations involving maize (Museo de Culturas Populares 1982). Many of these preparations require different types of maize. The livestock and poultry industry fabricates animal feed with maize, and this industry is a major user of imported from the U.S. The starch industry, through starch and its byproducts, provides products for different industries: the food, pharmaceutical and preserves industry and it is also used in the textile, paper and adhesives industries, among others (FIRA 1995).

I.B.2 Patterns of change

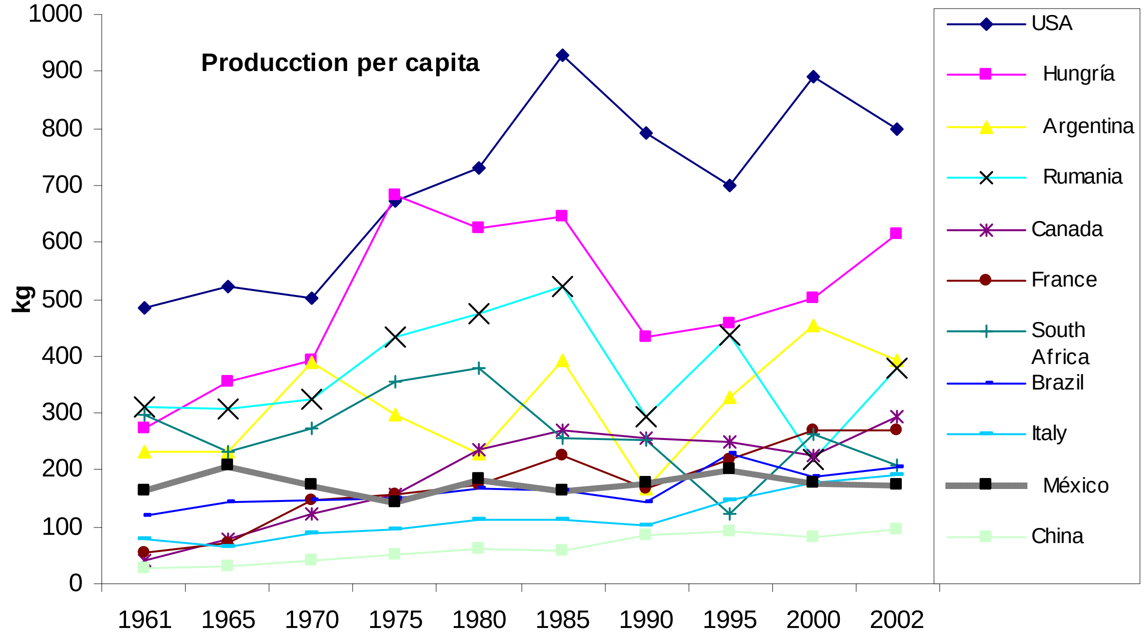
I.B.2.a. Integration into the national market and economic system

The development of agriculture has tended to draw together the labor and biological processes of agriculture and to replace local and on-farm inputs (e.g., plant nutrients, weed and pest management) with off-farm, industrially manufactured inputs. Off-farm inputs reduce cost of production by increasing the returns to land and labor, but this is often accompanied by increasing market competition among farmers and by reducing agriculture's share of the overall labor market. The results of agricultural development include vertical integration and loss of local independence in the food chain. The economic and technological processes of development often are connected to policies of market adjustment, the opening of trade, international competition, and submission to international regulation in addition to national agricultural policies. However, in Mexico, agricultural modernization between 1950 and 1982 was pursued in a relatively closed economy with state subsidies and state-sponsored development. After 1985, Mexico withdrew state subsidies and opened itself to trade as a NAFTA partner. Increases in productivity have meant that only a part of the economically active population is dedicated to agricultural activities, and the rural population has decreased and tends to continue doing so.

It is in this context that biotechnology has appeared as one more mechanism in the industrialization of agriculture and competition in national and international food markets. Indeed, if we look at the composition of world exports by merchandise category, the segment corresponding to food, live animals, beverages and tobacco is eight percent. Thus, international food trade is a small segment for which many countries compete and in which industrialized countries may have competitive advantages.

The world production of maize must be located within the context described above. Figure 6.1 shows the main producing countries of this cereal and the distribution per capita.

Figure 6.1



Source: Based on FAO 2003.

The United States stands out as principal maize producing country and is the main exporter. Although there is some consumption of fresh maize in the U.S., the grain is considered fundamentally as a commodity for animal consumption and has different industrial uses such as: sweeteners, oils, starches, fuel and, more recently, through the use of biotechnology, pharmaceutical and other industrial products. Current research in genetic engineering is aimed at obtaining maize varieties that respond to said uses, since the production destined to human consumption is minimal.

Mexico has experienced profound economic changes since trade liberalization was initiated in the mid-1980s. The implications of globalization for Mexican agriculture have been the withdrawal of public economic support for the agricultural sector, modification of Article 27 of the Constitution, which regulates land tenure, and the disappearance of public service institutions that previously provided technical assistance and a government marketing structure for maize. For Mexico, NAFTA has meant a structural change in its economy, in comparison to the U.S. and Canada where NAFTA is more of a commercial agreement (Shwedel 1992).

Of all these changes, the one with the greatest repercussions is the end of subsidies for financing, production, and marketing of agricultural products, especially maize. In 1990, government expenditure for agricultural development in Mexico was 11.1% of the total national budget, and be 2000, this portion had shrunk to 3.5% (III Informe de Gobierno 2003). Although continued direct support for rural areas is provided by PROCAMPO,[8] funding for this program is not sufficient to foster agricultural production, above all because the amount proposed at the beginning of the program, which was to be continued for 15 years, has not been maintained.

Maize imports had begun before trade liberalization, and dependence on imported maize has increased since the beginning of NAFTA. Table 6.4 reports the amount and distribution of maize imports since 1994 according to grain type and use and shows the trend of increasing dependence on imports.

Table 6 .4

Mexican Maize Imports (metric tons)

	1994	1995	1996	1997	1998	1999	2000	2001	2002
White grain									
Millers	585 872	268 225	1 223 555	210 071	627 226	634 890	780 673	685 710	456 003
Conasupo	0	45 000	1 533 057	0	438 468	57 750	0	0	0
Diconsa	0	0	0	0	0	0	227 107	224 345	152 326
Industrial flour and tortillas	0	176 388	581 605	0	0	446 200	211 813	150 590	95 502
Sub-total	585 872	489 613	3 338 217	210 071	1 065 694	1 138 840	1 219 593	1 060 645	703 831
Yellow grain									
Starch	893 190	846 190	1 244 744	1 646 459	1 622 632	1 741 265	1 758 672	1 947 743	1 795 177
Cereal confection	11 787	174	0	68 410	66 911	88 965	74 353	117 477	125 058
Snack food	0	0	0	0	0	20 009	17 021	20 396	7 585
Animal feed	760 645	1 254 537	1 326 076	514 797	2 279 300	2 364 423	2 153 120	2 894 039	2 792 597
Sub-total	1 665 622	2 100 901	2 570 820	2 229 666	3 968 843	4 214 662	4 003 166	4 979 655	4 720 417
Total maize imports	2 251 494	2 590 514	5 909 037	2 439 737	5 034 537	5 353 502	5 222 759	6 040 300	5 424 248

Source: Secretaría de Economía, cited in Ortega and Bautista 2003.

The livestock industry is the primary user of imported grain, and between 1994 and 2002, this sector used 53.7% of the imported grain, followed by the starch industry, which used 44.3% (Ortega and Bautista 2003).

[8] Procampo consists of decoupled (*i.e.*, area-dependent and unlinked to productivity) income transfers to landowners. The transfers remain even if the beneficiaries turn to alternative crops (Dyer and Yunez-Naude 2003).

Although the initial plan under NAFTA was to allow gradually increased imports for a 15 year period and not to exceed 2.5 million tons as tariff-free, this plan has not been followed (FIRA 1998, Fritscher 1999, de Ita 2000). Between 1994 and 2001 maize imports exceeded the NAFTA quota by 13 million tons. The Government of Mexico has not collected allowable tariffs on imports above the established 2.5 million tariff-free quota, and the foregone tariff is estimated to be US$2.5 billion (de Ita 2003).

The industrial sector that depends on maize exercises a strong influence on government decisions regarding imports. The committee that recommends maize import levels includes government representatives from the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food Industry (SAGARPA) and the Ministry of Economy (SE) and representatives of the private industry including the livestock, flour, starch, and marketing sectors.[9] The advantages realized in acquiring maize outside of Mexico include lower prices and financial servicing through the Commodity Credit Corporation of the U.S.[10] Appreciation of hierarchical and power relations is important to understand the complexity of the actors involved decisions regarding the production, industrialization, and importation of maize in Mexico. Table 6.5 lists the various actors that participate in the production, commercialization and manufacture of maize.

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[9] Conasupo's place in the collection and distribution of maize, as of 1999, has been partially taken over by Cargill and Archer Daniels Midland. In the peasant and small producers sector, ANEC has been formed.
Cargill trades in food commodities and produces a great many of them: grains, flour, malt, corn, cotton, salt, vegetable oils, fruit juices, animal feed and meat. In 1998, Cargill formed a worldwide joint venture with Monsanto to create and market new products 'enhanced through biotechnology' for the grain-processing and animal feed markets (Brewster 2002). In 1999, Archer Daniels Midland acquired 22% of the shares in Maseca (de Ita 2000).

[10] The agricultural export support programs fostered by the United States government, through the CCC, guarantee financing for importers at very low rates, between 6 and 8% a year, with recovery terms of up to three years in the case of grains (de Ita 2000).

Table 6.5

Mexico: Social Actors in Maize Production, Commercialization and Manufacture

Abbreviations	Actor
1. EmpSemill	Seed companies
2. DueñoSem	Producers with their own seeds
3. ProdComer	Commercial producers
4. ProdSemi	Semi-commercial producers
5. ProdAutocon	Non-commercial producers
6. CapacExt	Training and technical extension
7. EmpIns	Input companies
8. INIFAP	National Forestry, Agricultural and Livestock Research Institute
9. CIMMYT	International Center for Maize and Wheat Improvement
10. UACH	Autonomous University of Chapingo
11. COLPOS	Postgraduate College
12. UnivEstatales	State Universities
13. Procampo	Direct support for the countryside program
14. FIRA	Agriculture-related trusts instituted in Banco de México (Mexico's central bank)
15. ADANIELLS	Archer Daniels Midland. Firm commercializing maize and with other businesses
16. CARGILL	Firm commercializing maize and with other businesses
17. ANEC	National Association of Firms Commercializing Farm Products
18. SAGARPA	Livestock, Rural Development, Fisheries and Food Industry
19. SEMARNAT	Ministry of the Environment and Natural Resources
20. CONABIO	National Commission for Knowledge and Use of the Biodiversity
21. SNICS	National Seed Inspection and Certification Service
22. Secreteconomía	Ministry of the Economy
23. CIBIOGEM	Interministerial Commission on Biosafety and Genetically Modified Organisms
24. CNC	National Peasants' Confederation
25. UNORCA	National Union of Autonomous Regional Farming Organizations
26. FPRODUCE	"Produce" Foundation
27. CNA	National Agricultural Council.
28. MOLNIXTAMAL	Nixtamal mills
29. MASECAGRUMA	Firm producing tortillas and maize flour
30. BIMBO	Bread company
31. MINSA	Corn meal producer/Maize flour company
32. ALBALANCEAD	Balanced feed producing companies
33. ALMIDONERAS	Starch and starch byproducts producing companies
34. EDULCORANTES	Sweetener producing companies
35. BOTANAS	Snack food producing companies
36. ACEITERA	Corn oil producing companies
37. GEF	Global Environment Facility
38. DICONSA	Public company for the rural supply of basic products
39. PROGRESA	National Education, Health and Food Program
40. TORTILLERIAS	Businesses dedicated to the sale of tortillas
41. MISCELÁNEAS	Stores selling several different products.

Figure 6.2

Schematic of interactions between maize actors in Mexico

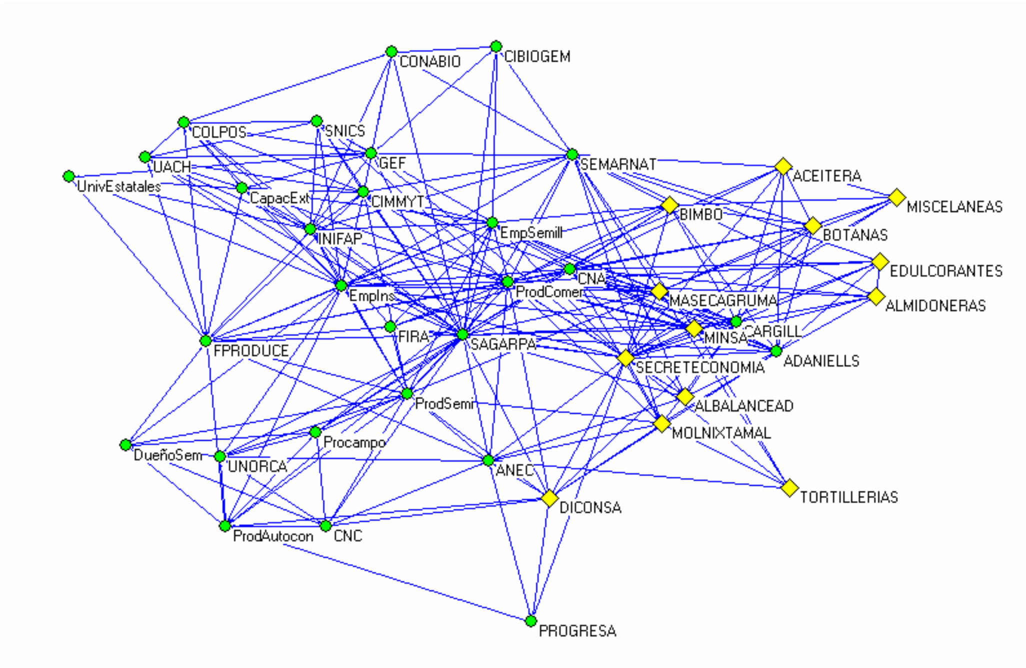

Figure 6.2, shows the interactions among the network of social actors associated with the production and distribution of maize. The circle (•) nodes correspond to actors in maize production and marketing and the diamond (♦) nodes are actors in the processing and distribution of maize and maize products. Connecting lines indicate linkage between actors. This figure shows that commercial producers, government institutions, and industrial sectors are central in relation to the peripheral role of non-commercial and semi-commercial producers, biosafety, and educational and research institutions.

I.B.2.b. Persistence of poverty

A shift in macroeconomic policy took place in the 1980s towards participation in the world market based on a *maquila* (in bond assembly) exporter and food importer model, without a period for preparation or transition. This shift produced serious repercussions in income distribution and the persistence of poverty in Mexico. Food imports increased from US$1,790 million in 1982 to more than US$10,500 nine years later. Maize producers lost 53% of their purchasing power; wheat producers 46.9% and soy producers 59% (Bañuelos and García 2002).

Although some rural sectors may have benefited from trade liberalization (Gladwin and Thompson 1995), the economic reforms within the globalization framework is widely viewed as reversing trends towards social equity (Hernández 2003). The perspective is not encouraging, agricultural supports continue to diminish as does direct investment aimed at agriculture. In Mexico, as can be seen from the demographic statistics, one of every four persons lives in rural zones (Warman 2002), and it is in these zones where the deepest levels of poverty are manifest.

Hernández L. and Velásquez R. (2003) analyzed the National Survey of Household Income and Expenditure for the period 1963–2000, and the results of their research are as follows: With the opening of trade, social inequality increased. In 2000, the population in a state of total poverty in Mexico was 51.3%, 30.8% of which is at a level of extreme poverty, that is, 31.1 million persons. With respect to the comparison between urban and rural poverty, the analysis shows that in absolute terms, total poverty is greater in the towns and cities. However, the number of persons in conditions of extreme poverty is greater in rural than in urban areas: 16.2 million in the former and just under 14 million in the latter. 65% of the inhabitants of rural zones are classed as extremely poor and 23% as moderately poor, which implies that 90% of the inhabitants of rural areas are lacking in some way (Hernández L. and Velásquez R. 2003). A regional analysis of poverty reveals that four-fifths of the total number of poor persons are concentrated in five socio-economic regions: the Capital of the country, the Center, Center Pacific, Center Gulf and South Pacific (Chiapas, Guerrero and Oaxaca), corresponding to 53% of the total number of poor persons (Hernández L. and Velásquez R. 2003).

I.B.2.c. Migration and decline in rural sector

The economic crises during the last decades have prevented the rural population remaining in their places of origin and stimulated the expulsion of manpower to the industrial-urban sector. This has also been a detonator for emigration abroad. Migration in the 1950s and 1960s was characterized by a movement from the countryside to the cities, mainly to Mexico City, and was temporary in nature, with the emigration abroad of some 700,000 persons a year. In the nineteen nineties, the migratory flow to the United States was permanent and the number of persons was calculated at 300,000 a year, principally of working age (Hernández L. and Velázquez R. 2003:109).

The zones that traditionally expelled manpower are located in the center and north of the country, Zacatecas, Durango, Aguascalientes and Michoacán; however, over the last few years, the south of Estado de México and Morelos, the north of Guerrero, the south-east of Puebla, the center of Oaxaca and Veracruz have been added to these. According to the National Population Council, 96% of Mexican municipalities have a certain degree of migration to the United States (Bartra 2002, Hernández L. and Velásquez R. 2003).

The migratory flow is a substantial variable that must be taken into account in the analysis. It is estimated that there are 25 million immigrants of Mexican origin living in the United States. The inhabitants of rural zones have been those who have had greater recourse to domestic or international migration. However, the phenomenon needs to be analyzed in detail, because its impact is not necessarily the total abandonment of rural work, since the monetary remittances the migrants send to their families, is invested in maize cultivation in some regions. The remittances sent during 2002 amounted to

US$9,815 million. Even though a part of these resources supports maize production, it is a fact that there is scarcity of labor in the country and those varieties of maize that need more work may be lost. Women, children and the elderly may not be fit enough to work in maize growing (Ortega P. 2003). The fact we are witnessing today is that the most vulnerable rural population is exactly the one whose territory harbors the genetic wealth of maize. As noted in Chapter 1, 70.61% of maize landraces and wild relatives come from a group of states that include the poorest and most rural states in Mexico.

I.B.3. State involvement in agricultural development in rural livelihoods

I.B.3.a. Pressures for technological improvement

Hewitt de Alcántara (1976) studied the modernization of Mexican agriculture between 1940 and 1970, and she observes that all less developed regions import technology that has been created elsewhere and under different social conditions. Moreover, she notes that less developed regions pay a high price for new technology not only in money but also in social organization. In addition to these costs, we might also note environmental costs, which are a possible concern related to the introduction of transgenic maize.

Mexican state involvement in the agricultural sector accelerated in the second half of the 1930s with the distribution of lands to *ejidos* and increased public investment. After this early involvement government efforts on behalf of agriculture slowed as emphasis shifted to industrialization. Public agricultural research oriented to food production began in the 1930s. Researchers were organized into the Institute for Agricultural Research (IIA). In 1945, the Office of Special Studies (OEE) was organized in association with the Rockefeller Foundation to initiate agricultural modernization through developing improved technology for maize and wheat production. Later, these efforts came to be known as the Green Revolution.

Mexican agricultural researchers experimented with improving open pollinated maize for small, traditional producers and some in the IIA initiated research on hybrid maize, which aimed at producers with more resources (Fuente H. et al. 1990). In 1961, IIA and OEE were merged into the newly formed National Institute for Agricultural Research (INIA). In 1963, the International Maize and Wheat Improvement Center (CIMMYT) was organized as a specialized center to develop improved germplasm for these crops.

A "package" of modern technology for maize comprised of improved varieties, chemical inputs, irrigation, and mechanization was promoted by the National Maize Commission, although this agency experienced difficulty in the distribution of improved seed, which was distributed also by a black market, and in competition with improved seed from different agencies. To resolve these problems, the Government of Mexico organized the National Seed Production Agency (PRONASE) in 1961. Nevertheless, private producers retained permission from the Ministry of Agriculture to continue receiving, multiplying, and selling seed directly from INIA (Hewitt de Alcántara 1976).

Technological innovation in the form of improved seeds and chemical inputs has clearly resulted in a worldwide increase in yields of Green Revolution crops, but at the same time the limits of this technology are apparent in marginal production areas. The Green Revolution technologies are not appropriate for all areas, and producers in marginal areas have not received the full benefit of these technologies. An often expressed concern is that these new technologies will result in the loss of diversity in crops, although the process of genetic erosion is complex and the loss of crop diversity may be less than previously predicted (Ortega P. 1973, Brush 2004).

I.B.3.b. Technical assistance

The modernization of Mexican agriculture has been accompanied by a relatively weak system of agricultural extension and other technology transfer mechanisms, especially to non-commercial and semi-commercial producers (Hewitt de Alcántara 1976). Nevertheless, there have been important developments in technical assistance to the small farm sector. One example is the Plan Puebla between the late 1960s and 1980s, which was aimed at rain fed zones in the Puebla Valley and which resulted in a significant increases in national production (Díaz 1992). In 1967, Plan Puebla reached 32 municipalities in the Puebla Valley, including 70 communities with an average farm size of 2.5 ha, on 116,000 ha, 80% of which was planted in maize. Plan Puebla was a joint project between the Postgraduate College of Montecillos and CIMMYT, and it sought to complement farmer knowledge and practices with new technology that was appropriate to local socio-economic and ecological conditions. This technology was designed to be economically favorable to the producer by offering affordable inputs that helped return a profit to the producer[11]. Investigators of Plan Puebla established that improved varieties did not compete with local varieties, so the program emphasized management practices such as planting densities and fertilizer use.

At the beginning of Plan Puebla, 103 peasant producers participated in the program in 1972, this number had grown to 6202 in 1981 when the Mexican Food Program (SAM) took over (Austin and Esteva 1987). One measure of Plan Puebla's success, was that at its beginning, 41% of the household income of participants was from off-farm employment while at the end of the project, this had decreased to 28%.

Maize yields in Puebla increased during the Plan Puebla project, although unfavorable weather in some years lowered production. In 1968, during project period, participants achieved yields of 3.985 t/ha, while non-participants in the valley obtained 2.090 t/ha. However, in 1982, yields of participants were 0.944 t/ha while non-participants obtained 1.3 t/ha. In 1982, participants no longer received the support of SAM, climatic conditions were unfavorable, and changes in the national agricultural policy led to increasing input costs. By 1989, producers had largely abandoned the recommended practices of Plan Puebla and returned to a maize deficit situation (Díaz 1992).

[11] The program elements included: (1) high yielding maize varieties, (2) information about agronomic practices, (3), diffusion to producers and agricultural leaders of information about the results of agricultural research, (4) adequate and timely supply of inputs, (5), credit availability at reasonable rates, (6) access to crop insurance, (7) a favorable relation between the costs of using new technology and its returns, (8) accessible markets that absorbed increased production at relatively stable prices, and (9) support for organizing producers to obtain credit, transport, and infrastructural development (Díaz 1992).

At the end of the 1970s, the Government of Mexico directed agricultural policy aimed at food security[12], and using financial resources from the petroleum industry, it embarked on an ambitious program to stimulate agriculture and recuperate national self-sufficiency. In 1980, it initiated the Mexican Food System (SAM) program aimed at peasant maize producers in rain fed areas as well as at poor urban and rural populations. SAM established a basic food basket for the 20 million poor people of Mexico. The axis of SAM combined subsidized credit, low cost inputs, and price controls for consumers and price guarantees for producers. SAM resulted in an increase in cultivated area and an increase of 17.4 million tons of grain production including 12.5 million tons of maize. Despite these accomplishments, however, SAM was applied unevenly because of political ties and constraints. An example of constraints in policies for technology diffusion was the practice of public credit facilities (e.g., Banrural) limiting credit to farms that adopted recommended varieties in addition to other inputs. These policies did not result in food self sufficiency for Mexico (Appendini 1992, Hewitt de Alcántara 1992).

In 1982, the collapse of oil prices, increased interest rates, and cancellation of external financing revealed severe problems in the agricultural sector. Economic instability connected to high inflation led to capital flight and difficulties in meeting international debt payment obligations. Amidst the national preoccupation with international debt, the issue of food security became a marginal issue and SAM was suspended.

I.B.3.c. State subsidies and market control

The aim of previous food policy of the nation facing rapid population growth was to guarantee minimum food necessities at affordable prices, a policy that complemented the national effort to contain salary increases. For several decades, the government set a price ceiling on tortillas, milk and bread. This ceiling was ended in the 1990s. Nevertheless, during difficult economic times, the government developed a policy favoring food security and national self-sufficiency by means of extensive state involvement in agricultural development. With trade liberalization, the policy has shifted to seeking food security through grain imports rather than supporting national production. Under the new policy, price guarantees were ended in favor of world prices, and simultaneously, government support to agriculture were restrained.

The government made an exception in this policy for maize and continued a decreased subsidy in the early 1980s. Between 1979 and 1982, maize producers received a 49% subsidy that was reduced to 21% between 1983 and 1988 (Fritscher 1999). Although a guaranteed maize price continued, high inflation, increasing costs of public services and credit affected the grain's production. Moreover, the commercial sector captured most of the state subsidy for maize.

During the 1990s, only maize and beans benefited from price guarantees, a policy that promoted their production. For example, producers in Sinaloa used to grow 40 different

[12] Food security is defined as an appropriate and sustainable equilibrium between self-sufficiency, employment and income generation, and natural resource conservation (Cota 2002).

crops, whereas today, they specialize in maize and tomato. Maize cultivation area doubled between 1990 and 1994 and maize production grew by 160% (Fritscher 1999).

This favorable situation for maize producers ended in 1994 with the signing of the NAFTA agreement. The policy of subsidies changed to direct support under the Program of Direct Agricultural Support (PROCAMPO), and the public sector's role in grain purchasing, marketing, and importation passed to the private sector. The national commodity purchasing and marketing agency (CONASUPO) was eliminated in 1999 (Yunez-Naude 2003). This agency was replaced by ASERCA, which operates an "indifferent price" program in which producers sell their crops to industry at the world price, and the government pays them the difference from an agreed price (Dyer and Yunez-Naude 2003).

CONASUPO played a central role in maize markets for many years with the objective of assuring supplies of the grain to different sectors of the population and especially to tortilla producers through regulating prices in commercial operations. However, responding to trade liberalization after 1994, the para-statal ceased purchasing grain from producers and reoriented its operations to providing maize to millers and to the national Distributor and Commercial Promoter of Basic Food Supplies (DICONSA). In this manner, the purchasing and selling of the major part of national maize production passed to private firms. These firms, in turn, have sought to change the source and processing of grain according to the new market conditions. Since 1995, the national price has been based on the world price of maize. Because of variations in world supplies, Mexican firms have depended on an intermediate scheme that values maize between the world price and a guaranteed national price that was established by CONASUPO. Under this scheme, producers can offer to sell their crop at higher prices than the world price, allowing them to capture some utility. This is especially true of commercial producers, such as those in Sinaloa, who employ modern technology and achieve yields above 3 t/ha.

Prior to the state's exit from purchasing and marketing grain, non-commercial and semi-commercial producers organized the National Association for Agricultural Commercialization (ANEC) in 1995 to promote marketing of maize, and other commodities. This organization has 60,000 peasant producers in 18 states who sell one million tons of maize (ANEC 2003).

During the 1990s, rural assistance programs were grouped into the Rural Alliance (Alianza para el Campo), and these included the "kilo for kilo" program whose objective was to increase yields through replacing traditional seed with certified seed of modern varieties, for both specific irrigated and rain fed areas. In seeking to increase yields through changing seed, this program tried to reach producers who were still using traditional seed but who worked in areas with agronomic potential. Certified seed was provided to selected producers at the equivalent price of farmers' seed, representing a potential saving and facilitated access to new varieties. By making commercial hybrids more accessible, this program sought to impact local maize populations through hybridization between the new varieties and farmers' varieties. The program was aimed at small producers with farms less than 5 ha who farm in areas where modern varieties are thought to have potential (ACERCA 1997). This program ended in 2001, in part because of farmers' concern that they could not purchase improved seed at subsidized prices and lacked their own seed.

Beginning in 1996, another program of the Alianza para el Campo is one of supporting the marketing of maize, especially by commercial producers. In 1998, this program supported the commercialization of 1.8 million tons of maize valued at 770.5 million MP. States providing the most grain to this program were Sinaloa with 69.7% of the total, Tamaulipas with 9%, and Jalisco with 8.7% (ACERCA 1999).

The policy of withdrawing state support from agriculture from state control and support in the national maize market has been accompanied by decreased investment in agricultural research and extension. The consequences of these policies include the lack of improved technologies, extension services that are inadequate or non-existent, insufficient or inappropriate use of inputs, weak or missing markets, scarcity of infrastructure, and lack of credit. While the national price of maize in Mexico is set at the world price, this does not account for subsidies and other forms of protection that industrial countries make available to their producers. The effects of trade liberalization in Mexico have been to deepen the crisis in the agricultural sector and to benefit only production of fruits, vegetables, and flowers for export. These policies have prompted many in the agricultural sector to seek off-farm employment and have reduced the ability of many communities to be self-sufficient.

I.C. History of maize management and diversity

I.C.1. Cultural aspects

Maize was domesticated in central Mexico between 9,000 and 6,000 years ago (Matsuoka et al. 2002). The crop diffused throughout the American continents before 1400AD and worldwide since 1500AD. Evolution of maize within its native homeland in Mesoamerica led to adaptation and diversification into approximately 55 races of maize (Sanchez G. et al. 2000) with locally recognized folk varieties. Maize was the keystone of Pre-Hispanic societies in the region, and it continues to occupy a uniquely important place in Mesoamerican civilization (Museo de Cultural Populares 1982, Pilcher 1998). The grain is the foundation of the region's cuisine and nutrition, the object of public policy and political discourse, and a central element in cosmology, iconography, ritual expression, folklore, and art. The title of a recent exhibition of maize in the Museo Nacional de Culturas Populares (National Museum of Popular Cultures) sums up the centrality of maize to Mexico: "Sin Maíz no hay País" – Without Maize there is no Nation. This sentiment is echoed in the language and mythology of indigenous cultures of Mexico. The Popol Vuh, the sacred book of the Maya, describes maize as the elemental substance used by Xmucané, the grandmother and creator of humans, to fashion the first Mayas (Recinos 1950). The *General History of the Things of New Spain* (the Florentine Codex), written originally in Náhuatl (ca. 1547) by Fray Bartolome de Sahagún (1979), elaborates the sacredness of maize to the Aztec people and the abundance of foods prepared with the grain.[13] For the contemporary Náhuatl of central Mexico, the word for maize is tonacáyotl—"our support" (León-Portilla 1988). Approximately 8 million hectares are planted to maize in Mexico, and the crop is the most widely cultivated crop in Mexico. Over 60% of the cultivated, rain fed area is devoted in maize (SAGAR, cited in Nadal 2000).

Seed selection is comprised of two general steps – (1) the choice of the varieties or types of maize that will be planted and (2) the choice of seed to be planted. Choice of maize varieties and the maintenance of maize diversity have been studied in several regions of Mexico, with an emphasis on small and medium size farms of the non-commercial and semi-commercial sector. Maize selection studies performed in the states of Chiapas (e.g., Bellon and Brush 1994), Jalisco (Louette et al. 1997), Veracruz (Rice et al. 1998), Oaxaca (Soleri et al. 2000), Mexico, and Morelos (Perales R. et al. 2003a and 2003b) show that the patterns of selection are generally similar across different regions and types of producers. Variation in selection is observed according to criteria such as grain size, whether rows are straight, and grain color. Farmers use multiple criteria in selecting. Yield is usually important, but concerns for quality, resistance to drought, wind, and disease, storability, and market demand are also cited by farmers. Commercial producers can be expected to choose maize types that will be most profitable in terms of having the lowest unit costs of production. Profitability is difficult to measure because of the use of family labor and the lack of a land market in many regions, but it appears to be elusive for many farms, especially those smaller than 2 ha. Perales R. (1998), who worked with semi-commercial producers in the States of Mexico and Morelos, and Dyer (2002), who worked with non-commercial producers in the Sierra Norte of Puebla, both find that maize production is not profitable to most producers, especially when family labor is calculated as a cost of production. Nadal (2000) calculates that farms averaging 2.4 ha and larger have profits, although it is not clear whether hidden costs, such as the value of family labor or land, are included in these calculations.

Having multiple criteria means that farmers are flexible in their choice of varieties to plant and plant different varieties to meet multiple criteria. However, diversity of maize in farms tends to be similar, and relatively low, across all three types of farms. Farms in all sectors are dominated by one to three varieties when measured by ecological indexes that consider dominance (evenness) as well as number of varieties (richness). By straight number counts (richness), non-commercial and semi-commercial maize farms are likely to be more diverse than commercial maize farms because of a tendency of larger commercial farms to purchase seed and to produce solely for the market. Non-commercial and semi-commercial farms often plant different varieties for home use and maintain minor varieties either in home gardens (huertas) or at low numbers in fields (milpas). Varieties that are acquired by inheritance and through the informal and local seed systems are identified primarily by color, although some researchers have found that farmers observe multiple characteristics in variety identification. For example, Mayan farmers in Yaxacaba, Yucatán use 13 characters in identifying their maize varieties (Argaez et al. 2002). The dominant type is usually labeled as “criollo” (“creole”) maize

[13] “The native inhabitants of Mesoamerica placed themselves in a cosmological food chain by offering sacrifices of human flesh to maize gods in return for vegetable crops to feed people” Pilcher (2000:163).

with the local meaning of “our maize.”

The difference in variety choice between the non-commercial and semi- commercial sectors and the commercial sector is not so much in criteria as in where to obtain seed. The observation by Louette et al. (1997) that there is a relatively high flow of seed between farms and villages has been confirmed in other studies (Rice et al. 1998, Aguirre G. 1999, Badstue et al. 2002, and Perales R. et al. 2003a). Non-commercial and semi-commercial farms largely provision seed from their own seed stores and from the local, informal seed market. Commercial farms tend to change their seed more completely and frequently. The contrast between commercial and other types of farms in seed turn over and provisioning is shown in the study by Aguirre G. (1999) of Guanajuato. Three quarters of the non-commercial and semi-commercial farms report either have no seed turnover or partial turnover, but 41-60% of the commercial farms report total seed turnover. The 20% national area planted in improved maize (open pollinated and hybrid) is concentrated in the commercial sector, although this sector also relies on local varieties. Farmers in the semi-commercial and commercial sectors often rely on local varieties that are advanced generations of improved varieties managed as landraces (“acriollados”) (Ortega P. 1973, Aguirre G. 1999, Bellon et al. 2003b). Farmers also attempt to acquire traits of commercial hybrids and improved varieties by crossing them with local varieties (Perales R. et al. 2003b). Selection of seed for planting is in non-commercial and semi-commercial farms is largely done post-harvest, and the selection process is often extended by the practice of adding seed during food preparation (Rice at al. 1998). However, some researchers report pre-harvest selection (Yupit M. 2002). Attachment to local maize is evidenced by the fact that seventy-five percent of Mexican maize farmers still plant local varieties (landraces) (Aquino et al. 2001). Within this seventy-five percent, an estimated one-third (i.e., 25% of all maize) is advanced generations of improved maize types, which may account for up to fifty percent of the maize area of Mexico (Ortega P. 2003).

Three strong patterns summarize research on variety choice and seed selection: (1) a preference for local seed among non-commercial and semi-commercial producers who represent 60 % of the production units, (2) careful selection of seed for local adaptability, and (3) relatively common use of seed that is acquired from other farms and villages. Although the amount of seed flow varies among regions and farmers (Oretga P. 1973), it is appropriate to describe Mexican maize agriculture among all types of producers as an “open system” because of the flow of seed, farmers’ efforts to acquire new traits, and their success at transferring traits from new varieties and types into local maize populations. Although the maize system is an open one, the movement of new varieties and traits is moderated by careful acquisition of seed from farmers and seed suppliers, selection according to local criteria, and experimentation on a limited scale followed by selection for how well a new variety fits into the local maize population. In other words, although the system is an open one, it is also conservative in terms of maintaining local populations.

Although traditional farmers have conserved native populations of maize, the loss of landraces has been inevitable. Among the causes that have led to the loss of genetic diversity, mention should be made of substitution by improved varieties; reduction of maize area because of crop substitution, and migration which reduces the availability of labor or causes abandonment of agriculture. Thus, the phenomena of poverty and migration may have had an influence on the loss of diversity in maize because of abandonment of the crop or reduction in the cultivated area due to lack of producers. However, the current national political and economic environment is to remove stimuli from the production of maize with local varieties and to force migration of the working age population.[14]

I.C.2. Maize livelihoods

Producing maize as a livelihood means that its cultivation underpins subsistence strategies of poor and economically disadvantaged households and helps them to maintain claims to economic and social resources in the rural sector. Abundant ethnographic evidence from rural Mexico testifies to the fact that maize plays a profound and complex role far exceeding that of a simple commodity. Maize tortillas are offered as sacraments; kernels are use in ritual divination; maize is accorded respect as a sapient being. So, growing a maize crop is evidence that a farmer is committed to the rural community, its connection to the past, and its values. The binding together of maize and rural community is evident in indigenous art and archaeology since before the European arrival in the New World. The connection is reaffirmed in the early European chronicles of life in Mexico at the time of the conquest (e.g., Sahagún 1979), and it is equally present in contemporary depictions of the essence of rural Mexico, such as in the murals of Diego Rivera, who used maize often in his murals depicting the birth and soul of modern Mexico. His homage to the agrarian foundation of Mexico in the vestibule of the Riveriana Chapel in Texcoco is decorated with a mural that is representative of the continued reverence toward maize in popular culture. Here, in Rivera's *The Blood of the Rural Martyrs: Emiliano Zapata y Otilio Montaño*, the two martyrs are buried beneath a field of maize, whose roots become an umbilical cord connected to the two graves.

Sixty percent of the maize producers in Mexico are in the non-commercial and semi-commercial sectors, and to these producers, the crop has a value well beyond being a marketable commodity. These sectors contrast to the commercial sector in their approach to maize. To non-commercial and semi-commercial producers, maize is a cultural and social keystone of their livelihoods. All or a large portion of the production is destined for home consumption rather than the market, and the crop represents the survival of the farm household in unpredictable and often threatening physical and social environments. Producing maize for home consumption means that farmers in the non-commercial and semi-commercial sectors are protected to some degree from the uncertainty of an economy that is often unfavorable because of frequent unemployment, the necessity to work away from home, inflation, and unstable prices for other commodities. Life in the larger national economy is perceived as a struggle and prejudiced against the rural poor,

[14] In communities with a high degree of migration, the producers who remain are advanced in years. "Half of the owners of agricultural property are over fifty years old, with an average life expectancy of seventy" (Warman 2002:5).

and producing a maize crop, albeit inadequate, provides a measure of security (León-Portilla 1988, González 2001).

Despite an emphasis on subsistence production, non-commercial and semi-commercial farm households have some connection to the market; they purchase inputs, and they sell a portion of the harvest. However, these households operate in environments where markets often are absent or very partial in terms of providing inputs such as modern varieties, alternative crops, fertilizers, pesticides, and information (de Janvry et al. 1991). Missing markets for seed, information, and other inputs explain the relative conservatism of farmers in these sectors in terms of variety selection and a preference for local seed. Likewise, the local market may be insufficient or unfavorable in supplying maize for consumption. Households in the non-commercial and semi-commercial sectors, therefore, cannot and do not want to abandon maize production, because of insecurity about their ability to purchase their basic staple. Thus, maize production occupies significant land and labor resources despite evidence that maize production is often "unprofitable." As mentioned above, many and perhaps most, households in the non-commercial and semi-commercial sectors, depend on access to the market to supplement their own production, but this dependence on the market has not led to the abandonment of local seed and emphasis on traditional management of agriculture. Limited amounts of maize may be sold, and maize is purchased with earnings from other activities such as off-farm labor.

Off-farm income is increasingly important to rural households, but maintaining viable links to the land and to rural communities is important both as an economic strategy and for cultural identity (Mutersbaugh 2002, Kearney 2000). Farms in the non-commercial and semi-commercial sector (up to 5 ha) earn less than 30% of their income from farming (de Janvry and Sadoulet 2001), yet the income share from farming is an essential part of the overall economic strategy of the household because it helps supplement low wages and unstable employment. Moreover, households in the non-commercial and semi-commercial sectors often farm communally owned (e.g., by *ejidos* or *comunidades*) land under usufruct rights. Although the Mexican Constitution was changed in 1992 to allow privatization of *ejido* lands, land management in former *ejidos* remains largely unchanged (Nuijten 2003, Johnson 2001). Following village norms and customs, such as participation in local religious activities, is expected in order to maintain rights to use land and to mobilize social networks for labor, seed, and other inputs (Wolf 1959). Cultivating maize is the culturally appropriate method for villagers and migrants to show their connection to the land and in some places to maintain rights and economic networks in the rural economy (Sandstrom, 1991). Perales R. (1998) found that part-time farmers who also worked in Mexico City planted maize but did not harvest it.

In sum, to many farmers in Mexico, maize is not a simple commodity that is grown or not according to whether it is profitable. Policies that affect the market value of maize affect the incomes of maize producers, but negative income effects do not result in abandoning maize but rather in household strategies to supplement income in other ways. Part of the livelihood aspect of maize is identification with local maize, even though there is turnover in maize seed. A new technology that radically alters the quality of maize through cross-pollination might well be interpreted by farmers as depriving them of maize types that are identified as local and part of their cultural connection to the land. Nevertheless, Mexican farmers' knowledge of seed selection and experience in evaluating and selecting new maize types suggests that unacceptable phenotypes will be effectively removed from their local maize populations.

I.C.3. Use of new technology

Mexico has invested in agricultural research and development for a century (Fernandez-Cornejo and Shumway 1997). It has built major centers for research and education, offered basic and advanced training to several generations, and organized a national system for technology diffusion that complements investment in transportation, communication, and other infrastructure (Hewitt de Alcántara 1976). While substantial progress in agricultural productivity can be related to investment in research and other agricultural development efforts (Fernandez-Cornejo and Shumway 1997), technical change among maize farms is uneven and production gains have been unable to meet increasing national demand.

Analysis of the diffusion of new technology reveals a gradient in adoption organized according to the technology in question as well as by different farm sectors. Thus, relatively few farming sectors can be described as being isolated from or fully integrated into the flow of new maize technology. The large majority of maize producers in Mexico has been exposed to new technology and can be described as partial adopters in two senses. First, new maize technology is rarely adopted as a "package" of inputs—seed of improved varieties, fertilizers, pesticides, irrigation, and mechanization. Second, new maize technology is adopted more extensively in commercial sector than among non-commercial and semi-commercial producers.

Diffusion and adoption of separate types of maize technology (e.g., improved varieties, chemical fertilizers, management practices, pesticides, mechanical tillers and harvesters) runs between limited adoption to relatively full adoption. Individual elements are accepted and other elements are rejected. This pattern is well illustrated in research in Mexico's central highlands (Perales R. 1998, Perales R. et al. 2003a, 2003b). It is difficult to estimate the frequency of adoption across different technologies, farm sectors, and environments, but if Perales R.s' (1998) findings in the central highlands are representative, chemical inputs are the most common new technology to be adopted. There is a declining order of adoption of chemical inputs: fertilizers, herbicides, insecticides, and fungicides (Perales R. 1998). Perales R. examined the adoption of improved maize along an altitude transect between the Amecameca Valley (2000 meters) in the State of Mexico and the Cuautla Valley (1400 meters) in Morelos. Perales R. (1998) reports that between 92 and 100 percent of farmers use chemical fertilizers along the transect between the Amecameca and Cuautla valleys. Other technologies adopted at low overall rates and the variation in adoption among different regions is greater. For instance, the use of commercial hybrids varied between none (Ayapango and Tlatltelco in Amecameca) and 43 percent (López Mateos in Cuautla).

The first type of partial adoption, breaking technological packages into different components and adopting individual components at different rates relates to two factors. First, partial adoption by type of farm is related to the economic and social resources available to the farm. These resources, in turn, are a function of farm size, quality of agricultural resources (e.g., altitude, soil, water), access to markets for information and agricultural inputs including credit, tenure, education, and off-farm income of the farm household. Partial adoption by type of technology appears to be largely a function of agricultural environment, such as altitude and moisture regime, and infrastructure such as irrigation. Farmers in the more favorable maize environments, such as lower altitudes with good moisture regimes, are likely to adopt more new technological elements than farmers in less optimal environments. Thus adoption of both chemical inputs and modern maize varieties is common among different types of farms in the mid-altitude region of the Grijalva Valley in Chiapas but only chemical fertilizer is used in the high altitude region around San Cristobal de las Casas (Brush et al. 1988).

A degree of linkage exists between the adoption of improved varieties and the use of purchased inputs such as fertilizers and herbicides. Because improved varieties are usually developed under favorable conditions such as deep soils and good weed control, they are adopted more readily on farms with these conditions. Advanced generations continue to exhibit similar yield improvements in favorable conditions. A result in Chiapas is that improved varieties of Tuxpeño and Vandeño races have displaced local varieties of the same races (Ortega P. 1973). Local types tend to persist on farms with less favorable conditions. However, in other regions, such as the Chalco Valley of highland Mexico, improved maize types have not displaced local ones on highly commercial farms that rely on purchased inputs (Perales R. et al. 2003a).

A second factor relating to partial adoption of agricultural technology is the common practice of subdividing farms into different plots, which often have different agronomic potential. This practice of fragmenting farm parcels allows a single farm household to adopt different technologies on individual plots. For instance, in the mid-altitude zones of the Grijalva Valley of Chiapas, households use improved maize varieties on parcels in the valley bottom that are plowed with tractors, and they used local varieties on hillside parcels that are plowed with oxen (Brush et al. 1988).

Finally, improved maize is is usually developed for tortillas but not for other uses, such as pozole (hominy soup). Traditional varieties are kept for these uses. It must be stressed that no single matrix of socio-economic, environmental, and location-related factors can predict or explain the adoption of agricultural technology in the maize sector.

The second type of partial adoption is the tendency for different types of farms (e.g., non-commercial vs. commercial) to adopt technology at different rates. Besides looking at individual technologies, adoption studies also show that different types of farms and farms in different environments generally adopt technology at different rates. The adoption gradient has relatively small groups of non-adopters at one extreme and full-adopters at the other. One non-adopter group that appears to be isolated and to maintain local and ancient maize production practices is the Lacandón Maya of southern Chiapas

(Nations and Nigh 1980). Relatively full adopters of new maize technology are farms in the commercial sector in Sinaloa (Sanderson 1986) that have achieved maize yields (8.9 t/ha) comparable to those in the U.S. (SARGAPA 2003). Perales R. et al. (2003a) and others (Brush et al. 1988) show that improved varieties are more likely to be adopted in lower zones, below 1500 meters. Higher zones (e.g., 2000 meters) are consistently conservative in terms of the reliance on traditional varieties.

Here also, it must be stressed that a single matrix that contrasts farm types and environments cannot account for the observed variation in adoption of new maize technology. For instance, we might think that adoption is a matter of social and economic isolation with more commercial farms having higher rates of adoption. Perales R.'s research is significant for showing that this simple socio-economic matrix cannot account for the observed pattern of using improved maize varieties. Amecameca is close to Mexico City, maize is a commercial crop there, farm households are integrated into the national market economy, and the area has been a focus of agricultural research for at least five decades. Cuautla, on the other hand is more isolated from the national economy and agricultural research and its farmers produce maize as a subsistence crop. Nevertheless, maize technology diffusion, as measured by the adoption of improved maize varieties, is more notable in Cuautla than in Amecameca (Perales R. et al. 2003a). In this case, households in the more economically integrated and commercial maize area rely almost exclusively on local maize varieties, while households in the more economically isolated and subsistence oriented area plant modern maize varieties, including commercial hybrids. Similarly, Aguirre G. et al. (2000) found that the diffusion of improved maize in Guanajuato did not follow a pattern whereby farms that were most advantaged socially, economically, and environmentally were likely to adopt improved maize at a higher rate than farms that were less advantaged.

Partial adoption by type of farm and technology means that a large majority of Mexican maize farmers are aware of new technology, experiment with it, and choose what elements to adopt and which to ignore. Thus, Perales R. et al. (2003b) found that Amecameca farmers were familiar with improved varieties and commercial maize hybrids but had decided that local varieties were a better choice. Ortega P. (1973) described the practice in Chiapas of interplanting improved and local seed in order to obtain better, locally adapted varieties. Likewise, in Cuautla, farmers interplanted improved and hybrid maize seed with local varieties in an effort to move desirable traits into local varieties (Perales R. et al. 2003b). This practice is reminiscent of "creolization" described by Bellon (Bellon and Brush 1994; Bellon and Risopoulos 2001) in the Grijalva Valley of Chiapas where farmers manage improved varieties similarly to their management of landraces. Here some older, improved varieties are fully adapted and virtually indistinguishable from landraces, while newer, improved varieties are restored by periodic purchase of new seed. One result of creolization is to change local populations of maize to meet the farmers' desire for particular traits. Another result is to make it virtually impossible to identify a "local" or autochthonous variety from a "foreign" or exotic one. This difficulty is emphasized and illustrated by Louette's (Louette et al. 1997) research on the types of maize and seed management in Cuzalapa, Jalisco. Maize seed in Cuzalapa has a small but regular turnover and an input from outside of the local village. Farmers there consider a maize variety to be “local” if it has been grown in Cuzalapa for 15 years and “foreign” if it has been present for less time. Louette concludes that the maize currently grown in the village is not the same maize as that grown a generation ago, even though the maize in question is a farmer-managed landrace that might otherwise be thought of as "traditional."

Louette’s research in Cuzalapa motivated researchers elsewhere to investigate the flows of maize seed in local maize production systems. While the rate of seed replacement in Cuzalapa is high compared to other study sites, the importance of seed exchange and turnover beyond community locales has been reported for Chiapas (Brush et al. 1988), Jalisco (Louette et al. 1997), Mexico (Perales R. et al. 2003a), Oaxaca (Badstue et al. 2002), Puebla (Van Dusen 2000), and Veracruz (Rice et al. 1998). The turnover of seed in Mexican maize production mirrors that in other areas that have been described as having “local” and “traditional” agriculture and crop populations (Zeven 1999). This research has changed the way of describing crop populations and seed systems in centers of crop origins and diversity from an emphasis on the localness of crops and the closed nature of seed systems to picture crop populations and seed systems are open and organized as metapopulations (e.g., Zimmerer 1998).

The open character of maize populations and seed systems in Mexico is an apt analogy for the nature of technology diffusion. In recent decades, new technologies have appeared regularly. While technological adoption is often limited, very few farming systems can be described as technologically closed. Rather, they are open to new technology but generally cautious to adopt. The result is that few Mexican agricultural systems have experienced dramatic and rapid changes such as experienced in the U.S. with mechanization and the diffusion of commercial hybrids or the in parts of Asia where the Green Revolution occurred between 1966 and 1980. Nevertheless, incremental change and partial adoption of new technology are commonplace in almost all of Mexico.

Another type of technology that has affected maize producers is the development of industrial maize flour (harina de maíz) for the commercial production of tortillas. Tortilla manufactures, such as Maseca and Minsa, purchase only grain of certain size and standards, and local maize types are often not accepted. Maize producers who sell grain are required to change types or to sell at lower prices in different markets. For instance, the producers in the Chalco Valley have lost their traditional outlet because the Mexico City market is now dominated by flour based tortillas (Ortega P. 2003).

I.C.4. Social and economic impact of maize technology development in Mexico

Although the diffusion and adoption of new maize technology is partial, agricultural development in Mexico is significant and logically has social impacts. Views on the social impact of maize technology development in Mexico reflect the range of opinion evident in social impact assessment elsewhere (Lacy 2001). De Janvry and Sadoulet (2002) note that technological change has both direct and indirect impacts on poverty, and the same might be said about technological impact in other areas. Direct impacts include increased productivity of land and labor, greater food security, lower cost of production, and increased income. Indirect impacts include lower prices for food and employment and wage effects in agriculture (de Janvry and Sadoulet 2002).

Social scientists are divided in their conclusions about bias in agricultural technology in Mexico. One group, represented by Hewitt de Alcántara (1976), concludes that agricultural research and technology in the country have an urban-industrial bias that is unfavorable to the poor and to small producers. While agricultural technology is theoretically scale-neutral, the conditions of different producers allow the wealthiest farms to benefit most from new technology. In other words, by not being specifically pro-poor, agricultural technology is de facto pro-rich. To this group, the result of technological change has been increasing impoverishment of peasant producers and increasing control by wealthy, industrial producers.

Another group of social scientists differs in their conclusion about the impact of technological change in Mexican agriculture. This group includes Bellon (Bellon and Risopoulos 2001, Bellon et al. 2003a) and de Janvry and Sadoulet (2002). While this group recognizes the persistence of poverty, it finds that agricultural technology, such as chemical fertilizers and improved maize varieties, benefits peasant producers. An implication is that the cause of continued or worsening poverty cannot be attributed to technological change and that new technology may alleviate poverty. In a simulation of the impacts of different scenarios of technological change, de Janvry and Sadoulet (2002) estimate that with new technologies small and medium farmers in Latin America capture greater benefit and suffer less decline from falling commodity prices than large farmers. Bellon researched the use of improved, open-pollinated maize varieties in Oaxaca and Chiapas. Extremely poor, poor, and non-poor farmers cannot be sharply separated in their use of maize varieties that are descended from hybrid or improved, open pollinated varieties. The rate of using these varieties does not conform to the trajectory from extremely poor to non-poor, and farmers in all three categories recognize the traits of improved maize as being beneficial to them.

I.C.5. Impact of demise of subsidies, technical assistance, and market controls

A serious obstacle in assessing scale bias or other negative aspects of new agricultural technology is isolating the direct and indirect effects of technological change from the myriad of other changes that simultaneously affect rural populations. A case in point in Mexico is the changes in public programs of subsidies, technical assistance, and market controls that directly affect maize producers (Ochoa 2000). Mexican governments have been proactive for nearly a century in efforts to improve conditions in the agricultural sector although the distribution of benefits is affected by political ties. Land reform, infrastructure development, education, technology development and diffusion, price supports, market controls, and direct subsidies have played significant roles in the Mexican countryside, and the ebb and flow of these policy implements and public investment play a more prominent role in living standards and rural conditions than production technology. Research on the effects of public policy on Mexican agriculture is more extensive and detailed than that on technological change and there is greater consensus that policy is the more significant factor. An important, and perhaps predominant, consideration of agricultural and food policy since 1930 has been to procure low-priced grain for urban consumption.

Public policy has the potential to affect the three maize sectors and maize producing regions differentially. For instance the post-revolution land reform that was implemented on a large scale in the 1930s was intended to benefit non-commercial and semi-commercial producers in contrast to the 1992 land reform ending the *ejido* system that is interpreted as benefiting commercial producers at the expense of others (Barkin 2002, Appendini 1994). Policy initiatives that were broadly beneficial to the different types of maize producers include the subsidies and price supports of the Systema Alimentario Mexicano program in the early 1980s (Austin and Esteva 1987). Nevertheless, the objective of providing inexpensive grain for urban consumption may be more important to policy makers than enhancing the welfare of rural producers.

Trade liberalization that allows expanded maize imports and the closing the state commodity authority (CONASUPO) were policy changes in the late 1990s that are widely viewed as having negative impacts on non-commercial and semi-commercial producers (Nadal 2000, Yúnez-Naude 2003, Wiggins et al. 2002). Nadal (2000, 3) concludes that the liberalization resulting from these policy changes "threaten the ability of Mexican farmers to continue to grow corn and the ability of consumers to afford it." Declines in commodity price for maize following liberalization did not result in a decline in the area or production of maize (Dyer and Yúnez-Naude 2003). This persistence of maize is explained by the cultural and socio-economic importance of maize and by remittances form national and international labor migration that now is a primary income source for non-commercial and semi-commercial producers (de Janvry and Sadoulet 2001).

I.C.6. Relation of transgenic maize to other technological change

Transgenic maize, which was developed outside of Mexico and has not sanctioned for cultivation there, is similar in some regards to long-standing practices of public and private sector crop breeding in Mexico. This technology is the product of centralized scientific programs and not a technology that farmers have developed. Both transgenic and conventional crop breeding have expanded the use of wider gene pools to obtain useful traits. The intention of both conventional breeding and transgenic crop development is to derive crops with traits that are valued by farmers and/or consumers. Transgenic crop development, however, differs from conventional breeding in three ways. First, transgenic crops use material from distant and unrelated gene pools. Second, a novel method of gene insertion is involved in creating transgenic crops. Third, there is a tendency for this type of crop development to be done privately and as intellectual property rather than by public breeding and as public goods. Transgenic maize for Mexican conditions could be developed by public breeding programs, but as noted above, the Government of Mexico has withdrawn support form public research and extension, thus making the public development less likely. Whether the products of transgenic crop development will behave differently in the Mexican maize system is also a pertinent question.

While the inclusion of novel germplasm from distant gene pools is a characteristic of transgenic crop development, this step arguably is merely a logical progression of the trend in crop conventional breeding to utilize germplasm from ever more distant sources. Progressing from selection within local populations to crosses among populations, crosses of crop lines from distant regions, and wide crosses across species within a crop's lineage, crop geneticists have continually extended the range of diversity and complexity of the pedigrees of the crops (Poehlman 1995). Likewise, apart from expressing transgenic traits such as Bt or herbicide tolerance, gene insertion has not been shown to produce plants that are different from plants produced by conventional breeding methods in terms of grain type or other phenotypic characteristics. Nevertheless, these facts are not widely recognized or understood by the public, and some view transgenic methods as radically different from other types of crop improvement.

The proprietary nature of transgenic crops makes them dissimilar to conventional crop breeding in many countries, where public breeding is the dominant form of crop improvement. Historically, Mexico has been an example of this type of country. Privatized breeding creates the possibility of social inequity because, unlike the earlier technology, which existed as a public good, biotechnology is marked by a prevalence of private firms, patents, and licensing. Thompson (1997) outlines two social inequities that might result from the proprietary nature of transgenic crops: (1) farmers will be deprived of rightful compensation for property they already own, and (2) farmers will be deprived of important future economic opportunities.

The possibility that the creation of transgenic crops will deprive farmers of compensation reflects the idea of "biopiracy" that commercial seed involving genetic resources acquired as common heritage goods represent a taking of farmers' property. While the charge of biopiracy has been used for a decade or more, the term is ambiguous and not legally defined, and definition is complicated by the practices of treating biological resources in agriculture as public domain goods. In Mexico, these practices include such activities as sharing of seed among farmers, replanting commercial seed and seed of improved varieties, and efforts by farmers to achieve the transfer of phenotypic traits through hybridization. The UPOV78 framework that is accepted in Mexico includes exemptions for farmers and breeders that allow them to replant protected crop varieties and use them to create new varieties without licensing from the originator. Mexico does not have rules to prohibit the collection and shipment of maize within the nation or to the outside. The national collections of maize maintained by INIFAP are integrated into the international system of gene bank access and exchange. These practices relating to common heritage and the public domain mean that traits from farmer varieties are accessible to commercial breeders just as they are to other farmers and crop breeders, and they may be used to create commercial varieties as well as new farmer varieties. In other words, commercial breeders can benefit from the public domain in the same ways as farmers. So, a charge of biopiracy because of commercialization contradicts the long-standing and widely used practices of managing maize germplasm in Mexico, and Mexico does not have a national policy to prevent open access to maize germplasm.

Moreover, a charge of biopiracy is difficult to sustain in the context of Mexican policy not to allow patents on crop varieties and in the context of the impending implementation of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA) (see section II.C.1 below). That treaty includes maize as a crop that is covered by its provision that no intellectual property can be claimed on germplasm in the form received from the international germplasm system (e.g., the CIMMYT gene bank). Although Mexico has not signed or ratified this treaty, its main trading partners in NAFTA have either signed (U.S.) or ratified (Canada). Taken together, the lack of patents for crops in Mexico and the ITPGRFA, strongly suggest that patenting of farmers' varieties is not likely.

The possibility that farmers will be deprived of future economic opportunities might be realized in different ways, for instance by removal, patenting, and commercialization of farmer varieties outside of the international germplasm system covered by the ITPGRFA. Although most germplasm is accessed through the international system, it is not the only way that germplasm can move between countries with different approaches to patenting crops. The Enola Bean patent (Rattray 2002) typifies the negative impact on farmers from patents issued for crops that are undifferentiated from farmer varieties. This patent may be inappropriate, but it seems unlikely that transgenic crops will increase the likelihood of similar inequities. The value of transgenic crops is their difference from farmer varieties.

However, another negative consequence from the shift to private research and transgenic crops is likely. This consequence is that the rise of private research will cause or accelerate a decline in public funding and research for agricultural development directed to the poor. The decline in publicly supported maize research following the rise of the hybrid maize industry (Kloppenburg 1988) shows the effect of a shift in agricultural technology on the research system. Until recently, the balance of research for developing countries was public, but this appears to be shifting (Pray and Umali-Deininger 1998). The possibility of bias that hangs over public research is yet more probable for private research. The high investment required for developing transgenic crops means that companies working in developing countries are likely to target commercial crops and farm sectors. The negative aspect of this is that private research expenditures will off set public ones, leaving the small farm, subsistence sector without a research system working on its behalf.

The final issue is whether transgenic maize will perform differently in the maize system of Mexico. As noted above, the acceptance of modern varieties and commercial hybrids has been very limited despite several decades of research and development. Several researchers (Ortega P. 1973, Bellon et al. 2003, Perales R. et al. 2003b) point out that the dichotomy between "modern" and "traditional" maize varieties is inappropriate because of the common practice of acquiring modern varieties, attempting to cross them with local maize types (Perales R. et al. 2003b), and then managing modern varieties in the same fashion as landraces are managed. Nevertheless, many studies show that landraces continue to be present in almost all maize farming systems and dominant in most (Aguirre G. et al. 2000, Bellon et al. 2003a, Perales R. et al. 2003a). Transgenic maize is likely to be met with the same attitudes of caution and conservatism as commercial hybrids and open pollinated varieties. Non-commercial and semi-commercial maize systems are not usually included as targeted areas for developing new maize varieties, and the cost of developing transgenic varieties will reinforce this pattern.

However, non-commercial and semi-commercial farmers do acquire seed of new varieties and experiment with it (Bellon and Risopoulos 2001, Perales R. et al. 2003b), and valued traits from these activities may persist in maize populations managed by farmers. Although corn borers are present in Mexico, they are not perceived as a problem and they are not managed with insecticides or other cultural practices. Thus, the Bt property of transgenic maize may not be valued by Mexican maize farmers, especially if it is associated with a yield penalty or other negative traits. However, if perceptions change and the technology is understood to limit damage that is seen as unacceptable, Mexican farmers will be positive toward it. Because Bt technology also targets the fall armyworm (*Spodoptera* spp.), which is definitely a major pest of maize in Mexico, as well as the corn earworm (*Helicoverpa zea*) and Mexican corn rootworm (*Diabrotica* spp.), it may be advantageous to Mexican farmers. Collectively, these pests of maize result in significant yield and quality losses annually in the country.

Herbicide use is widely practiced, especially in the tropical regions of Mexico, and because of this practice, intercropping in the traditional milpa has been reduced. Provided that glyphosate herbicides are used, herbicide tolerant maize may have some positive value for farmers in all three maize sectors because of the possibility to reduce labor and/or herbicide costs. An advantage to herbicide tolerant maize would be to avoid intensive weeding and herbicide application before planting, which are done to reduce the presence of weeds after planting. However, where current traditional cultural practices persist in the non-commercial and semi-commercial sector, herbicide tolerant maize should not find favor. These practices include intercropping maize, beans, and squash, collection of weedy vegetables (quelites – *Chenopodium* spp. and *Amaranthus* spp.), and not using top-spaying methods in the application of herbicides.

II. Potential Effects of Transgenic Maize on Farmer Choice and Rights

II.A. Effects of previous maize improvement on farmer choice

As pointed out in previous sections, maize choice in Mexico has favored the maintenance of traditional maize populations. However, it must be stressed that these populations are open systems in the sense that non-local material, including germplasm from improved and modern maize, is often acquired, evaluated, and incorporated into farmers' maize populations (Ortega P. 1973, Louette et al. 1997, Bellon and Risopoulos 2001, Perales R. et al. 2003b). This widely observed pattern suggests that the most important aspect of farmer choice is the freedom to acquire and evaluate new "foreign" maize varieties and to incorporate new material and maize traits into local populations through farmer managed hybridization or by "creolization" (Bellon and Risopoulos 2001).

Several characteristics of the present maize system facilitate the openness of maize populations and farmer practices of incorporating new germplasm: (1) farmer attitudes about the public good nature of their seed, (2) the public nature of the most active and wide-spread crop breeding programs, and (3) lack of strong intellectual property (e.g., utility or industrial patents) for privately derived crop varieties. These characteristics mean that a farmer may openly acquire new maize types from other farmers, markets, crop breeding programs, or private seed companies, and replant without prejudice the material or progeny of crosses in his fields that contain traits from the new maize types. Previous maize improvement, both public and private, has not fundamentally changed the choice of farmers, but they have made material available that was not previously present in localities and regions. Examples are the introduction of South American races and Tuxpeño derived material in Chiapas (Ortega P., 1973, Bellon and Brush 1994) and material from commercial hybrids with lodging resistance and drought tolerance in Morelos (Perales R. et al. 2003b).

II.B. Potential effects of transgenic maize on farmer choice and rights

Provided that transgenic maize does not have drastic effects such as causing unviable seed, yield reductions, or alteration in food quality, this maize per se should have no more effect on farmer choice and rights than previous maize improvement. In other words, there is no inherent difference in transgenic maize that affects farmer choice and rights. As mentioned in section I.C.6., transgenic maize differs in three ways from maize varieties developed by crop breeders: (1) sourcing germplasm from distant gene pools, (2) gene insertion in new ways, and (3) development in private rather than public breeding programs with a greater reliance on intellectual property. The fact that traits are sourced in distant gene pools should not make transgenic plants significantly different to farmers from varieties that public and private crop breeders release and which use germplasm from national collections and international gene banks. Gene insertion has also not proven to produce plants that differ from those produced by other breeding methods.

Development in private breeding programs, which rely on relatively restrictive intellectual property tools such as utility patents, is another distinguishing characteristic of transgenic crops. The potential effect of this aspect on farmer choice and rights in Mexico depends on whether Mexico develops and enforces restrictive intellectual property protection for crop varieties, such as utility patents in the U.S. Less restrictive intellectual property, such as UPOV-like Plant Variety Protection (Baenziger et al. 1993) which incorporates breeders' and farmers' exemptions, would have little or no impact on the current practices of farmers' choice of varieties or other types of farmers' rights. The current practice in Mexico not to use patents for crop varieties means that private development of transgenic maize will have no greater impact than the development of commercial hybrids or open pollinated varieties by private companies.

II.C. Farmers' rights (i.e., the right to replant, exchange seed)

The evolution of intellectual property rights has made possible the protection of new plant varieties. Because the determination of "novelty" is often problematic, intellectual property may occasionally be claimed on crops or other plants that are currently in use in peasant and indigenous communities. When this occurs it may be viewed as an infringement of the rights of the rural communities (González 2001), and unlike commercial breeding companies, these communities lack the knowledge and financial resources to challenge inappropriate patents. Of the various forms of intellectual property protecting crop varieties, patents and plant variety protection are the most common. International coordination of intellectual property has been promoted through various international agreements and institutions, although each nation is responsible for developing and enforcing its own system of these rights.

II.C.1. International Treaty on Plant Genetic Resources for Food and Agriculture

The International Treaty on Plant Genetic for Resources Food and Agriculture (ITPGRFA) was agreed to in 2001. The treaty's Section IV establishes a multilateral system (MLS) of exchange and benefit-sharing for crops identified and included in Annex I of the treaty. Maize is included in Annex I (FAO 2001b). Mexico has neither acceded to nor ratified this treaty. Canada has ratified it and the U.S. has signed but not yet ratified it. Not all PGRFA of the crops in Annex I are automatically included in the multilateral system. The resources are limited to those Annex I crops that are under the management and control of parties and in the public domain and material in the gene banks of the International Agricultural Research Centers and other international institutions as provided in the treaty. An important aspect of the MLS is the principle that intellectual property protection (or other rights that limit facilitated access to the PGRFA) cannot be sought on material ", or their genetic parts or components, in the form received" from the system. This language is ambiguous and will likely be heavily discussed by the Governing Body of the Treaty once it enters into force. The issues affecting IPR are important because in some legal jurisdictions—such as the US and Canada—it is possible to patent DNA sequences that have been isolated from plant material without any structural modification. It is therefore possible that a patent holder could restrict use of the protected material even if it was obtained from within material from the MLS. Some argue this is necessary to encourage innovation while others believe it amounts to misappropriation of resources and is contrary, at minimum, to the spirit of the ITPGRFA.

Another important aspect of the treaty is the recognition that it gives to farmers' rights. In article nine of the ITPGRFA, farmers' rights and proposed to recognize the enormous contributions that local and indigenous communities and farmers have made, particularly those in the centers of origin and crop diversity. The treaty encourages nations to develop programs of farmers' rights that will encourage farmers to continue to conserve and develop plant genetic resources (Brush 2004). The ITPGRFA defines farmers' rights in several ways: (a) protection of traditional knowledge relevant to plant genetic resources for food and agriculture, (b) the right to equitably participate in sharing benefits arising from the utilization of plant genetic resources for food and agriculture, and (c) the right to participate in making decisions, at the national level, on matters related to the conservation and sustainable use of plant genetic resources for food and agriculture.

II.C.2. Mexican IPR relating to plant varieties and plant patents

México is part of the UPOV78 Convention, the TRIPs Agreement and NAFTA. In 1994, the country approved a new Law of Industrial Property, which allows patenting of microorganisms, transgenic animals, transgenic plants, bacteriological organisms, and isolated and purified gene sequences (Article 15). However, the law does not permit patenting of material directly from nature without substantial manipulation and modification (González 2001). Article 16 stipulates that "Inventions that are new, result of an inventive activity, and susceptible to industrial application will be patentable, in the terms of this Law, except: (a) essentially biological processes for the production, reproduction and propagation of plants and animals, (b) bacteriological agents and geneotypes found in nature, (c) races of animals, (d) the human body and the living parts that compose it, and (e) crop varieties." The 1996 Federal Law of Vegetal Varieties further defines and limits legal protection for crop plants to plant variety protection following the UPOV78 guidelines (González, A. 2001:90). Under UPOV78, Mexico allows a) protection of select the vegetal species; b) guranteee the right the farmers' right to replant and to exchange seed of protected varieties, c) the right of breeders to use protected material without restriction. Taken together, Mexico's Law of Industrial Property and Law of Vegetable Varieties mean that crops cannot be patented and that farmers and breeders may reproduce protected crop varieties for cultivation and scientific purposes.

II.D. Potential IPR issues

II.D.1. Distortion of agricultural research agendas

Agricultural research in Mexico between 1940 and 1990 was done primarily with public financing. However, under current policies public funding for agricultural research and extension has declined. Moreover, the high costs of research in biotechnology prompted scientists worldwide to seek private funding. Thus, biotechnology depends to a greater degree on financing by private firms. These firms, in turn, rely on intellectual property rights to make research profitable.

The private sector of the industrialized countries is in the vanguard of biotechnology for agriculture, and this sector determines the direction and objectives of the biotechnology research agendas elsewhere. However, biotechnology that has been developed for farms in the commercial sector and in prime agricultural regions cannot be assumed to be suitable for small farms or marginal areas. Because private companies must make a profit to continue research, biotechnology that is designed to reach small farms and less advantaged regions should be a mandate of public research institutions (González, R. et al. 2003). In order to continue benefiting small farmers in the non-commercial and semi-commercial sectors, research must incorporate the participation of poor farmers. Tripp (2000) notes that agricultural biotechnology is still not widely accepted by the public even though it has the potential to help poor farmers. However, Tripp (2000, 16) also warns that the potential to help poor farmers may be lost "if it is seen as simply a cynical strategy to gain support, or if it turns out to be a vain hope, unable to realize its good intentions." Tripp (2000) urges governments and proponents of biotechnology to also support policies that are favourable to poor farmers in terms of their participation in the market and in political representation. Smallholders must be seen as equal partners in the processes that develop technology in their name. Likewise, Chrispeels (2000:5) argues that "Agricultural research for the crops and problems of the poor has to proceed from the bottom up, not from the top down. Crops have to be created that fit not only in the agroecology of the poorest regions often characterized by marginal and heterogeneous environments, but the crops must also fit into the social and economic systems."

II.D.2 Closure of open seed exchange

Open seed exchange and hybridization is widely practiced in Mexican agriculture. The introduction of transgenic maize may affect these practices in two ways, although both are unlikely. First the possible use of genetic use restriction technology (GURT) may introduce a sterility trait (FAO 2001b). This is unlikely to have major impact for two reasons. First, this technology has never been used in Mexico and it remains a hypothetical technology for most crops. Currently it is not used in any crop in the world. Second, if GURT were to be used and accidentally crossed with farmer varieties, the trait would be rapidly eliminated by natural processes and farmer selection. Another possible effect on open seed exchange may be through the enforcement of intellectual property claims. As noted above, however, Mexico does not allow patents on crops and thus it does not have a strong mechanism to stop farmers from using novel traits that are patented elsewhere. The farmers' exemption that is part of UPOV protection allows farmers to replant seed and does not affect the dispersal of individual traits by normal cross-pollination. In sum, transgenic seeds should have no effect on traditional practices of seed exchange among farmers.

III. Potential effects of transgenic maize on productivity, yield, and income

III.A. Multiple determinants of productivity, yield, and income

Estimating yield or income effects of choosing specific maize varieties or types is unrealistic in the complex and heterogeneous maize system of Mexico. Yield is only one of several concerns to farmers. Estimating a potential yields from experiment stations is widely known to be unreliable for predicting performance under actual farm conditions. Moreover, experiment station data for transgenic maize is not available for Mexico, making an estimation of farm level effects even more troublesome. Possible yield effects might be suggested by data from other countries, such as the U.S. However, the agronomic and economic conditions of the U.S. or other countries where transgenic maize is grown are so different from those in Mexico as to invalidate the comparison. The same problems beset estimation of income effects of transgenic maize. Income estimation in non-commercial and semi-commercial maize sectors is hampered by a lack of data and the practice of producers of not valuing critical inputs such as seed, land, or household labor (Perales R. et al.1998, Dyer and Yunez-Naude 2003).

Yield is an indication of how well adapted a particular crop or crop variety is to a specific environment, and farmers' success at selecting better-adapted varieties is shown by significant yield increases before the advent of modern breeding (Evans 1993). Yield is important to farmers because it is obviously correlated with food and income. Nevertheless, yield is one of several concerns that farmers have in crop selection, and it may not always be the most important criterion (Bellon 1996). Considering yield alone is rarely sufficient to comprehend farmer selection or crop diversity. Yield is an ambiguous concept. Are we merely measuring the weight or volume of edible grain, or are other products such as straw or husks also to be counted? In parts of Mexico, the *totomoxtle* or outer husk of the maize ear, which is used to wrap tamales, is nearly as valuable commercially as the maize grain itself (Perales R. 1998). How do farmers calculate yield when the quantities of grain and other products are not positively correlated, for instance when fodder, which is a function of plant height, is reduced to allow higher grain yield?

Yield is notoriously variable across different micro- and macro-environments, and it varies according to cultural practices such as planting density, fertilizer use, and pest control. In Mexico, a wide range in reported maize yields results from environmental and management differences among farms and from the fact that their crop is genetically diverse. Perales R. (1998) gathered farmer estimates of yields in four communities along an altitudinal transect in the states of Mexico and Morelos. A wide range of yields was reported within a single community and maize type. For instance, in Ayapango (State of Mexico, 2400 meters), the average reported yield for Chalqueño maize was 1.9 t/ha (SE 0.13) with a range between 0.2 t/ha and 5.6 t/ha. Although Chalqueño is considered to be a single landrace, it is maintained as a population of genotypes rather than a single genotype, and the result is variability in qualitative and quantitative characteristics across the different environments where it is grown (Herrera C. 1999).

Quality may be equally as important as quantity in calculating the benefit of a particular crop variety. Quality is even more ambiguous than yield as a criterion, potentially masking many other relevant aspects of the harvest. Taste, processing and cooking qualities, resistance to pests and spoilage during storage, and market demand have all been shown to affect selection. Because quality may be negatively correlated with quantity, it is reasonable to treat yield and quality as though they are separate criteria in selection. Although tortilla quality is a primary criterion, special uses of maize are also relevant in evaluating quality. These include colored maize, large grained white maize for pozole, and fresh maize. Although special-use maize may not occupy extensive land, it can be important to some farmers.

Perceived risk of crop failure or yield instability may be as important to farmers' decision making as consideration of quantity or quality of the harvest. We have long recognized the importance of "safety first" in the decisions of subsistence farmers (Lipton 1989, Scott 1976). A farmer may be confronted with different microenvironments and yields among fields. More importantly, some crop types are better able to withstand unstable or threatening conditions such as drought, flooding, wind, weeds, insects or other predators, and disease. Farmers who are fortunate enough to have sufficient agricultural resources and supplies can control the effects of these conditions with irrigation, drainage, wind breaks, herbicides, pesticides, fungicides and other chemicals. However, many of these amendments are not available to most farmers, and they must meet these threats by selecting crop types that are resistant or tolerant to negative conditions, possibly at the expense of yield.

III.B. Yield effects

III.B.1. Possible differentiation in yield benefits by environment

Maize yields are determined by numerous variables and are grown over 8 million hectares in Mexico, with contrasting environments, management practices, and production objectives. One possible social impact of technological change is that it will be aimed at certain environments and by lowering the costs of production in those environments new technology will increase the income disparity between environments. This type of concern has been a focus of social scientists who see an urban-industrial bias in technological change (e.g., Hewitt de Alcántara 1976, Barkin 2002). As noted above, however, the record of technological change indicates that technologies are not adopted as "packages" and some technologies are widely adopted across environments and farm types. Although there is a tendency in Mexico for modern maize technology to be adopted at a higher rate in some regions and farm types, Perales R. et al. (2003a) find that no single matrix can explain the complex patterns of adopting technological change.

New technologies that depend on private sector development are likely to be targeted for optimal maize environments and commercial farm sectors. The dominance of landraces in the non-commercial and semi-commercial sectors and in highland environments above 2000 meters has not been changed by nearly 60 years of public and private maize breeding, although these breeding programs undoubtedly have had an impact on landrace populations. The existing types of transgenic maize that are grown outside of Mexico, especially those with herbicide tolerance, may be attractive to all farm types, but private development will predictably focus on the commercial sector. Farmers in the non-commercial and semi-commercial sectors may attempt to move advantageous traits into their landrace populations as they have with traits from other modern varieties (Perales R. et al. 2003b). For instance, farmers who use herbicides may well want to have herbicide tolerance in their maize populations..

The income effects of lower commodity prices for maize derived from declining costs of production are buffered in the non-commercial and semi-commercial maize sectors by production for household consumption and by their need to purchase maize (Dyer 2002, de Janvry and Sadoulet 2002). It is doubtful whether transgenic maize production in Mexico will have a significant income effect in the context of a national market that is open to imported maize and no longer has government involvement in marketing grain.

III.C. Farm income effects

In the context of trade liberalization, biotechnology represents an element of competitiveness along with agricultural restructuring in which some producers are displaced by others. According to this logic, agricultural restructuring caused by new technology is not considered as a negative social impact but rather a reflection of the success of more efficient producers. In other words, agricultural change is viewed in the same terms as market competition in other economic sectors. Nevertheless, when confronting a traditional production system, where the criteria or productivity is not the only measure of social and cultural value, the social impacts of new technology may be viewed differently. Thus, social impact among non-commercial and semi-commercial producers from the loss of traditional crops or genetic erosion in those crops because of the effects of hybridization with transgenic crops may be seen as a negative impact.

In Mexico, given the diversity of producers, ecosystems and agricultural practices, the assessment of the impact on income or, more broadly speaking, the socio-economic repercussions of the introduction of transgenic maize seeds, calls for multiple interdisciplinary studies per region. Under the risk of generalizing, an approximation can be made of the positive or negative socio-economic impacts of the use of said seeds according to the producer typology we have presented.

The commercial farmer participates in the formal seed market and purchases the necessary supplies year by year or for each cycle. The purchase of a transgenic seed will be in accordance with the balance made between the increases in yield and production cost, as well as market conditions. If transgenic maize is developed for superior grain quality for tortillas, it will be attractive to commercial producers and others. If the consumer accepts maize from transgenic seeds and profits increase or are maintained as a result of cost reduction arising from the new attributes of the seeds, the commercial farmer will include them in his fields. However, this adoption may be discouraged if transgenic maize that is cultivated for tortillas also affects other maize types that are kept for special uses.

The semi-commercial farmer would operate with a similar reasoning, however, he would be in a more vulnerable situation because he does not have the practice of buying seeds year by year and the supply of his own seeds could be reduced. This is the case of the producers of Veracruz who adopted the “kilo for kilo” program of Alianza para el Campo (Alliance for the Countryside); when the program was suspended they were unable to pay the market price for the seeds and they had not stored their own seeds.[15]

Finally, the non-commercial or self-consumption producer can be affected if his seeds are pollinated with transgenic seeds and their varieties lose the desired qualities, or if they lose their diversity as specialization or monocrops become more the custom. Peasants constantly select their local seeds, stressing several criteria, including their adaptability to low input conditions and according to different uses of the grain and other parts of the plant.

The practice of looking for improvements in the seed leads all producers to experiment, either through the purchase of new seed, exchange of seeds with other producers, or mixing local seeds with commercial varieties. The possibility exists that producers will

[15] The price per kilo of seed with the subsidy was $100.00 pesos (US$10.00) when it was $500.00 pesos (US$50.00) on the market. Direct research, spring-summer 2001 agricultural cycle.

experiment with grains for consumption as seeds,[16] and thus plant maize seed with transgenic properties. However, most farmers are keenly aware of the need to plant familiar seed that is adapted to their conditions, so the experimentation with exotic seed is on a very limited scale.

In the international debate on the potential effects of genetic engineering on agricultural biodiversity and biosafety, the need has been expressed to assess to what extent the GURT could be a mechanism to avoid the undesired escape of genetic material to neighboring individuals. Nevertheless, there is the risk that the open pollinated species could cross with GURT varieties and give rise to a reduction in yield in successive years due to the presence of sterile seeds in neighboring fields (FAO 2001b), although the fact this technology has never been deployed and the unlikelihood of widespread population impacts seem to reduce the threat.

Most producers who receive the benefits of hybrid seeds do so because they have been produced for a homogeneous environment and will meet yield expectations when they are accompanied by determined conditions of handling and inputs. These producers are likely users of transgenic seeds. For traditional producers, their strength lies in the heterogeneity of their milieu. In fact, maize diversity allows them to sustain themselves. Non-commercial and semi-commercial farmers are likely to emphasize characteristics, such as adaptability to low input conditions, and use qualities that may not typify transgenic maize varieties. These producers may also seek to maintain access to niche markets that link their ecological niche with an economic one, as happens with organic agriculture.

IV. Effects on cultural practices, identity, and customs

IV.A Maize in Mexican identity (livelihood vs. commodity)

One of the historic characteristics of Mesoamerica is its type of predominantly agrarian economy. The region is a center of crop domestication and development, including maize, amaranth, beans, squash, chili, green tomato, cacao, and avocado. After more than four millennia of crop evolution in the hands of farmers, the average size of the maize cob had grown six-fold. With this beneficial morphological change, linked to the development of larger, standardized grinding instruments, maize began to play a preponderant role as a food (Niederberger 2001). It was thus that maize cultivation became deeply rooted in the culture and identity of Mesoamerican communities and several of their customs and traditions are associated with this crop, for example the *tequio* or *gelaguetza*[17]

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[16] The reasoning behind this practice is clear and simple: if the the grain is suitable and good for consumption, why is it not so for planting? Opinion expressed in an interview by a peasant woman who has planted DICONSA's maize. Capulalpan, municipality of Ixtlán, Oaxaca, 14 January 2004.

[17] Tequio is a custom in the state of Oaxaca. In Zapoteco they say *tznia yeeti,* which means work for the people, in other states it has different names. It consists in citizens carrying out work of social benefit imposed by the citizens themselves, for example in the planting or harvesting of maize. The guelaguetza is the custom of giving economic, material or personal help to a family, which subsequently offers help to those who gave it, in reciprocity (Belmonte 2003).

From their relationship with and knowledge of nature, peasants incorporate environmental criteria into their production decisions, as well as socio-cultural ones such as storage quality of different maize types, the ease with which the grains can be removed from the cob, the softness of the dough, the color and flavor of the tortillas, the possibility of preparing other products, yield of the maize in home gardens, and its suitability for chicken and pig feed or stubble for cattle. As it is difficult for one plant to meet all these criteria, two or more varieties with different characteristics are commonly used: white maize for *tortillas*, red maize for special dishes, yellow maize for chicken feed. Hence, where self-consumption is still the main destination of the harvest, the selected varieties have changed little (Chauvet et al. 2003; Bellon, et al. 2001).

Up to now the State has placed emphasis on productivity. Government programs have focused on aspects related to an increase in yields with improved seeds, without considering the socio-cultural criteria the peasants give to maize cultivation. Food policies have concentrated on the supply of sufficient amounts of grain at low prices. Although this food policy is beneficial to consumers, especially for the poor, it has not taken food quality into account. Nor has public policy achieved poverty alleviation or created the favorable context necessary for the development of the peasants' capacities and for maintaining their quality of life (Appendini. 2001). While it is essential to increase food production, it is also necessary to ensure that the increased production contributes to widespread economic benefits and poverty alleviation (de Janvry and Sadoulet 2002, Tripp 2000).

Appendini and her collaborators have investigated the extent to which the communities of the Sierra Norte de Juárez, in Oaxaca[18] value not only on supplying themselves with maize as an essential part of their food basket, but also supplying a product that satisfies the conditions of color, flavor, and cooking quality demanded by local tradition and allows them to continue producing a crop under low input conditions. This approach gives equal emphasis to access to food and food quality (Appendini et al. 2001). This research helps explain why peasants devote themselves to maize cultivation even though production costs are higher than the price of purchasing maize on the market.[19]

In sum, cultural importance is separable from agricultural importance based on "profitability." Native varieties may be revalued using different mechanisms, for example, giving publicity to certain festivals organized in the maize growing regions or establishing a link between ecological niches and market niches. These approaches may give value to local maize that is appreciated for its flavor and texture. "The creation and strengthening of market niches for native maize products is a powerful stimulus for its conservation and improvement" (Ortega P. 2003:153). In fact, this mechanism has been

[18] It should be pointed out that this research was done before the finding of the introgression of transgenic elements of maize into cirollocriollo maize.

[19] The average cost per kilogram of the criollo maize produced can be as much as $5.43 pesos, considering the total costs of family resources like labor force, land, inputs for the plots. If monetary costs alone are considered, this average decreases to $1.33 pesos a kilo, close to the purchasing price in the local market of white, non-criollo maize, that is $1.56 a kilo on average, while it is $2.00 for criollo maize (Appendini et al. 2001:10). In January 2004, in the community of Capulalpan, white selected criollo maize, that is, the special maize used for atole or pozole, was sold at $6.00 a kilo. Direct research.

considered to be a more significant impact than genetic material rescue programs (Bellon et al. 2003:414).[20]

Mexico is a country with intermediate development and with tremendous heterogeneity and diversity in terms of physical environments, biological species, crops, cultures, and types of agricultural production. It is necessary to accept that there are different types of farmers with different cultivation practices and objectives. The use of a transgenic technology cannot be introduced without adequate biosafety measures, including public sector research and training aimed at the numerous non-commercial and semi-commercial producers in Mexico. The diversity of maize, management, and environmental conditions in which the grain is grown makes it impossible to unify a single technology for all maize farmers (González et al. 2003). In this complex environment, the challenges for using biotechnological products in a responsible way are multiplied, since greater human, technical and economic resources are needed as well as types different organization to guarantee biosafety and to distribute the benefits of new technology widely (González et al. 2003).

IV. B. Fluid nature of cultural identity (communication, migration, education) and absorption of new elements.

The cultural identities of social groups have different ways of expressing themselves in the face of modern processes, these may be assimilation, transculturation, recreation or resistance. In some rural communities, identities that have been constructed over many generations suffer a process of rupture as a result of migration, above all, if migration becomes permanent. In others continuity is given through the social networks that are created among those who stay and those who go. As Bartra (2002:22-23) observes, “It is really a question of give and take. The migrants help sustain their native villages with money, electronic devices and the cultural influences of the American, but they have a close rearguard that gives them roots, identity… Thanks to the polytopy of those who go away without going and the stubborn multifunctionality of those who stay, but not completely, the peasants are still our contemporaries.” The repercussions of migration on agriculture practices are complex: on the one hand, young men and women leave their villages to subsist or find better options for their lives and maize cultivation is abandoned, and, on the other, migrants send money that is invested in the planting of maize, among other things. Be that as it may, migration is likely to have contributed to the loss of genetic diversity as mentioned above.

With respect to the role of women in the cultivation of maize, they have always taken part in the different tasks. For example, in the Mazahua communities, it was the man’s role to prepare the land, he would dig it over with a “*coa*” or spade for planting, while the woman put the seeds in the ground as a symbol of agrarian fertility. With regard to the

[20] “ At least in the case presented here, enhancing farmers’ welfare is consistent with the maintenance of a local repertoire of varieties, and genetic erosion may be neither inevitable nor irreversible. The challenge is to make the existing diversity known and available to farmers willing to use it, rather than organizing rescue operations for genetic resources. This provides a positive outlook for on-farm conservation as part of a strategy to conserve crop genetic resources.” (Bellon et al 2003:414).

responsibilities for social reproduction, the woman was responsible for food and hence social action spaces were assigned: private or domestic spaces were the woman's domain, while the men devoted themselves to production, the economy and politics, that is, a public social space. In the social programs, programs to improve nutrition and family well-being are still in the female sphere and agricultural technological promotion is in the male sphere (Vizcarra 2001).

IV.B.l. Cultural notion of "criollo"—is transgenic maize different?

"Criollo" is a term that is widely used by Mexican farmers to refer to their local maize types (Bellon and Brush 1994, González 2001, Perales R. et al. 2003a). These local varieties may be considered as native, although, as with other crops, continual change over time is part of maize evolution. As Louette et al. (1997) showed, farmers consider seed to be "local" even though there is a high turnover in movement of seed between farmers, communities, and regions. Rice et al. (1998) and Perales R. et al. (2003b) also show that farmers are open to using new varieties. In this sense, "criollo" means seed that is adapted to local conditions rather than seed that is autochthonous. Seed selection is a mechanism that influences the persistence of characteristics in farmers' crop populations.

Transgenic maize seeds can have the same fate as hybrid seeds which have been accepted by relatively few producers because they do not compete well with farmers' varieties. However, there is concern about phenomena that happen but are not seen. The main concern about the release of transgenic organisms into the environment and maize production is that cross-pollination will allow gene flow, which will alter the characteristics of the existing populations. This concern is particularly sharp for transgenic varieties of maize that are being developed for non-edible uses such as polymers or pharmaceutical products. The unintended movement into the food chain of transgenic maize that was not meant for human consumption—for example, the Starlink maize and Prodigene incidents—have raised concerns that inadequate biosafety might allow unacceptable or even dangerous transgenic traits to enter the food chain.

IV.B.2. Women's participation in technological decisions

Women's participation in maize production varies among different types of producers and under changing demographic and economic conditions. An essential aspect of non-commercial and semi-commercial production is that it is a household activity in which men and women share different tasks according to their physical abilities and knowledge. Activities that might be carried out separately by men and women eventually result in production to benefit the household, and decision making reflects the household rather than one or another gender. For instance, in the Sierra de Santa Marta of Veracruz, seed selection is nominally a man's activity at harvest time. However, Rice et al. (1998) demonstrate that women contribute equally to seed selection during the year as they select seed while preparing food. In a context of widespread labor migration, the roles of men and women in managing agriculture are changing as women take more responsibility for production. Nevertheless, men continue to be involved in some activities and in technological decisions that involve the use of capital from remittances.

IV.C. Potential effects because of the loss of variability and local autonomy in production.

The loss of variability may pose a threat to non-commercial and semi-commercial producers, but as argued above, transgenic maize is unlikely to accelerate the loss of variability in Mexican maize. Mexican maize agriculture is highly heterogeneous in terms of environments, types of producers, and management practices. Pressures on maize diversity have been present for many years, yet there is widespread conservation of traditional maize varieties. The current pressures on maize producers, especially poverty, an unfavorable economic and political environment, and migration pose greater and more immediate threats to maize diversity and to the local autonomy of production.

The introduction of chemical fertilizers, herbicides, and improved maize types affected the diversity and conservation of traditional maize as well as changing Mexican society and culture. The introduction of transgenic maize has the potential to have similar effects. However, maize agriculture and Mexican society and culture are dynamic and will experience change whether transgenic maize is introduced or not, and Mexican farmers have shown that they are capable of managing their maize populations to limit or encourage change from new varieties. Whether transgenic maize will accelerate change or provoke unique or undesirable consequences in the country's maize is impossible to predict, but the possibility of this warrants further research. Asymmetry among different types of maize producers and the economic vulnerability of non-commercial and semi-commercial producers also weigh strongly in favor of further research and a broad public input regarding the decision whether to promote transgenic maize in Mexico. It is possible to evaluate transgenic maize on a case-by-case or trait-by-trait basis, although the possibility of unintentional diffusion of transgenic traits through open pollination greatly complicates any evaluation. Moreover, new transgenic traits that are not present in Mexican agriculture, such as the ability to produce pharmaceutical and industrial products, are actively under development. The opening of the country to transgenic maize cannot be evaluated solely according to the Bt and herbicide tolerant traits that are currently and widely used in maize.

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