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Theme: The paradox between Crop Genetic Resources Conservation and Crop Yield Increases by Small-scale Farmers in Mexico: *The maize case.*

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Research work

a Mara,

desde lo más profundo de mi corazón

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Index

1. Introduction

Conservation of Crop Genetic Resources (CGR) is now considered an important component of sustainable agricultural development. If conservation of genetic resources for agriculture is to be successful, a more complete understanding of the dynamics affecting traditional (landrace) crop populations is needed (Perales, 2003a). And on the other side, approximately 24 millions of Mexican inhabitants (rural & urban areas) have problem to access food supply (<www.jornada.unam.mx> June 30, 2005) and their high rate of demographic growth demand a long term effort aimed at improving their productivity and income. The incorporation of new technologies into existing maize production systems should help achieve these goals (Sain, 1999). Exploring the adopters and non-adopters socioeconomic characteristics and the factors that influenced to small-farmers' adoption is essential, because the non-adopter conserve maize biodiversity[1] *de-facto* and the adopter of Modern Varieties (MV) and technology package may cause erosion of maize biodiversity (mono-cropped) and pollution, but, the adopter improve food security, increase crop yield and food supply. Brush (1992) analyzed the loss of biological resources in agricultural systems due to the introduction of high-yielding or MV which represent a potential cost of agricultural development. Their findings provide empirical evidence that biological diversity on individual farms declines significantly as the area in improved varieties increases. Many related questions concerning the determinants of technology adoption and conservation of CGR are still unanswered. How do small farmers respond the paradox between conserved CGR and Improved Crop Yield? What are the determinants for the decision whether or not to plant a Modern Variety? What factors influenced their choice? What Agricultural Policy Reforms affect the choices of small-farmer decisions? What is the probability to switch from Traditional to Modern Varieties? Are there farmers that have both traditional and modern varieties, or mixed ones? The objective of this *Tesina* is to develop a farm-level econometric model that explain the probability to switch from Traditional Varieties (TV) to MV, and the technology adoption rate and extension of MV, fertilizer, herbicides and pesticides, which may explain the complexity adoption and non-adoption of MV in time, space and quantity. The model

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[1] FAO calls to conserve "Biodiversity for Food Security". It will highlight biodiversity's role in ensuring that people have sustainable access to enough high-quality food to lead active and healthy lives <www.fao.org> consult June 2005.

could answer how do small farmers in the southern Mexico's territory take action in this paradox.

1.1 The Research Problem

In Mexico the small-scale farmers respond in two directions or contradictions: one is the huge need to improve agricultural yields, the need of food security and reduce vulnerability and poverty characteristics –the Mexican agricultural policy, in this way, promote the use of Modern Varieties, subsidize the use of fertilizer and pesticides as oil-based product, less electricity tariffs for the use of pumps-out water (irrigate-land), and mechanization, between others <www.sagarpa.gob.mx>; nevertheless, the Government efforts have not satisfied the goals despite the availability of improved maize varieties over the last 40 years and repeated Government programs to encourage their use (Aquino, 1998; Bellon, 2003), as of today improved varieties are planted only in one-fifth of the total maize area of the country approximately (Morris, M.L., and M.A. López Pereira., 1999). Most of this area is located in the commercial production zones of central and northwestern Mexico[2]. Hence, about four-fifth of the area under maize are planted to landraces[3] or recycled improved varieties[4] (*creolized* varieties[5]); and the second one is the environmental policy that promote the control use of fertilizer and pesticides, conservation of Crop Genetic Resources, prevention of the land erosion and pollution of ground and running-water, as one National Policy on environmental protection and natural resources. (*Ley general del equilibrio ecológico y protección al ambiente*-México, 2005). Additionally, small-farmers have to face the recent policy reforms in Mexico –for instance: granting property rights to the *Ejido*[6] land tenancy

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[2] Perales *et al* 2003a argue that: "…The pattern of dominance of traditional maize varieties in the Mexican highlands and a mixture of modern and traditional varieties of maize in the lowlands is widely known by maize breeders, but this pattern is, nevertheless, poorly explained. Its possible to find modern varieties or their advanced generations in many places of Mexico, but their presence about 2000 masl is nil." And once again in Perales *et. al.* (2005).

[3] *Landrace* refers to a locally grown maize population that has been the result of farmer selection and management over many generations (Bellon and Berthaud, Forthcoming in The World Development).

[4] *Seed Recycling*, saving seed from one season to the next is an almost universal practice among small-scale farmers. Farmers usually follow strict procedures to choose what they keep as seed for the next season. Saving seed is not only a practice associated with landraces or traditional varieties, and saving seed from hybrids is much more prevalent that generally believed (Morris et al. 1999).

[5] A *creolized* variety is an improved variety that has been under farmer management for several generations (M. R. Bellon personal communication).

[6] The latter farms, known as *ejidos,* were created as a result of land distribution following the Mexican Revolution of 1910. An *ejido* is formed by several small landholdings, each of which is assigned to an *ejidatario* (the *ejido* also have common lands). Most *ejidatarios* are small farmers, and most of the *ejidos*' lands in Mexico are rain fed and dedicate to staple production. Prior to the *Ejidal* Reform of 1991, the *ejidatarios* were not

in 1991, implementation of NAFTA in 1994, *peso* devaluation in 1995, dismantling of National Company for the People Subsistence in 1999, and the dissemination and introgression of transgenes into the maize landraces (Quist, 2001)-. Moreover the polarization and big disparities in the configuration of cultural, socioeconomic, geographic, and technological elements characterized contemporary Mexican agriculture. Maize production across different regions and social groups shows the contrast between industrialized production using advanced technology and commercial varieties and hybrid seeds and subsistence production relaying on elements of pre-Hispanic technology and traditional landraces in shifting cultivation. Despite these contrasts, however, all maize systems in Mexico are based on combinations of local and non-local and older and newer elements (Brush, 2004). The small farmers select their alternatives and options to confront this contradiction.

Recapping this paradox: firstly, increase crop yield, reduce maize production vulnerability, food insecurity and poverty characteristics imply to adopt MV (Open Pollinated Varieties [OPV], Hybrid [H] and Biotechnology Varieties -Gene Modified Organism [GMO]), approved by FAO (2004a), fertilizer and pesticides (technology packages), as agricultural policy objective; and secondly, call-for the *in-situ*[7] conservation of maize biodiversity imply to continue cultivation and management of a diverse set of Traditional Varieties (TV) by farmers in the agroecosystems where the traditional crop has evolved as center of maize domestication and origin[8] (Bellon *et al.* 1997) as one of environmental policy objective.

1.2 The Key Hypothesis

The maize agricultural system of small-scale subsistence oriented farmers can be characterized as open genetic system (Bellon, 1994). In these systems, multiple maize populations coexist as seed spectrum. Most seed is saved from the previous harvest (Morris, M.L., and M.A. López Pereira., 1999), though some seed may also be acquired

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allowed by law to sell or lease their lands, nor even to hire workers. In 1991, the Mexican Constitution was modified to abolish these limitations (Yunez, 2003).

[7] *In-situ* conservation of agricultural biodiversity has been defined as, "the maintenance of the diversity present in and among populations of the many species used directly in agriculture, or used as source of genes, in habitats where such diversity arose and continues to grow". It concerns entire agroecosystems, including immediately useful species (such as food crops, forages, and agro-forestry species) as well as their wild relatives that may be growing in nearby areas <www.ipgri.cgiar.org> (consult on may 2005).

[8] As Bellon (2004: 201) notes, "…almost twenty years after Ortega-Paczka's in 1973 studied of maize races in Chiapas, Mexico, all races reported by him for tropical Chiapas, except for *Zapalote Chico*, are still present in Vicente Guerrero in 1994. Finding all this diversity in just one *Ejido* may seem surprising".

from other farmers or even commercial source. Farmer may mix seed from different sources if there is no sufficient seed or they wish to experiment with or expressly modify maize populations (Perales, 2003b). Farmers may incorporate improved varieties and expose them to their conditions and management, fostering the local adaptation, a process known as "*creolization*" or "*hybridization*" (Bellon, 2001).

The non-adopter farmers who use TV's conserve maize biodiversity *de-facto* without fertilizer and pesticides, and their characteristics perhaps: poverty household, indigenous ethnic, literacy, not market and credit access, crop and plots diversification, tenancy of bad-land quality, and they are positioned in one side of the seed spectrum, and the most important not to obey or respond the Agricultural Policy. The adopter who use MV's possibly will reduce their maize production vulnerability and improves food security, may be diminished their poverty household characteristics and cause erosion on maize biodiversity (mono-cropped) and pollution (with a high rate of adoption in the use of fertilizer and pesticides as oil-based product), and possibly their characteristics are: access to credit and extension programs, education, income and activities diversification, maize production oriented to market, and locate in the other side of the seed spectrum, this group of farmers to obey or respond the Agricultural Policy. The third type of small-farmer may have both TV and MV or mixed seeds as process called hybridization or creolized (Bellon, 2001 and Perales, 2003b), with this practice may be reduced their *trade-off*, the vulnerability and poverty characteristics, and conserve maize biodiversity, possibly improving their food security, situated in the center of the seed spectrum. The third type uses less technology than adopter, but more than non-adopter and mixed seed because this technology is divisible, and the most important issue is probably to conserve CGR and Improve Crop Yield as an unaware-act.

There are many related research questions in this direction: What are the determinants for the decision whether or not to plant a Modern Variety? What factors influenced their choice of new technology? What Agricultural Policy Reforms affect the choice of small-farmer decisions? What is the probability to switch from TV to MV? Are there farmers that have both traditional and modern varieties, or mixed it? Does this last farmer conserve maize biodiversity and improve food security and reduce their vulnerability? How does a small farmer respond the paradox between conserve CGR and Improve Crop Yield? The majority of these questions could be answered with the adoption econometric model, because the dependent variable is multi-choice (as seed spectrum: in one side is located the Traditional Varieties and in the opposite the Modern Varieties), additionally a huge set of independent variables is needed, based on section cross data.

Through the seed-spectrum and rate of divisible technology adoption model may identify what kind of small-farmers conserves CGR and reduces its food insecurity or reduces the paradox.

1.3 The Theory Based

Econometric research on the adoption of MV sought to identify barriers to its diffusion in developing countries to keep the Green Revolution going. A large body of knowledge (i.e. adoption theory) emerged from this research on varietal choice[9], contributing that the farmers in developing areas face a multiplicity of constraints (e.g. lack of credit, infrastructure, or information) that prevent them from adopting MV. Theory suggested that some of this constraints (e.g. financial and information) would dissolve with the diffusion process itself, but the process could also be hastened through investment in infrastructure, research, and extension (Feder, 1985b). Adoption theory provides a foundation for the emerging research on farmer management of diversity, which thus embraced varietal choice as its main subject, obviously of seed flow and seed selection.

The adoption theory can help to understand why a number of small farmers take up MV and technology packages; some others cannot adopt and continue planting Traditional Varieties. As a picture, the section cross data could show every one of the small farmer characteristics and the factors that influenced their maize choice between a diverse set of seeds –as spectrum-, seed management[10] by gender, socioeconomic and demographic distinctiveness, ethnic and indigenous language, income and activities diversification, geographic influence in the maize production, cultural practices to growing maize, farm size, land tenancy, number of plots and quality land, between many others farm

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[9] Smale *et al* 1995 "…From the perspective of human ecology: *variety choice* can be viewed as a process by which a farmer assemble various bundles of traits to satisfy consumption preferences, meet specific production conditions, or fulfill marketing requirements. Small-scale farmers with multiple objectives often consider several attributes of varieties when choosing among them, including traits related to yield of grain and fodder as well as those related to their home consumption of staple and specially foods".

[10] There are three aspects to crop *management*: seed flow, seed selection and storage, and varietal selection. Ecologist and social scientist described crop management as a strategy to cope with risk and environmental heterogeneity and a way to satisfy diverse consumption needs (Dyer *et. al.*, 2003).

characteristics. Martinez and Roca (Martinez, 2001) pointed out that if strong sustainability of agricultural development is to be done well; a more complete understanding of incommensurability aspects have to be considered into account, i.e., the value of the maize production unit cannot be solely measured with financial criteria, but also requires consideration of social and cultural values relating to human consumption, adoption, management and animal feed. These are a lot of reasons to analyze the set of seeds as spectrum.

The unit of analysis is the farmer, who decides whether or not to plant a Modern Variety or Traditional Variety, given a diversity of potential objectives and constraints. And, the household-farm is the common starting point for modeling Technological Adoption (TA) and/or *in-situ* conservation of Crop Genetic Resources (CGR). The household is the basic unit of management where decisions and actions are taken that affect CGR and TA (van Dusen, 2005). The household is the consumer of household production and purchased goods with income from production or wage labor. It is also the producer, utilizing its own endowments of labor, land and other assets as well as purchased suppliers to produce agricultural commodities either for consumption and/or market sales. Finally, household face constraints in terms of their endowments, but specific resource or market constraints may affect crop choice.

The *Tesina* objective is to find an econometric model of technology adoption that meets small farmer characteristics of rural Mexico and shows the probability to switch from TV to MV as response of Agricultural and Environmental Policy, rate and extension of technology adoption of MV. By this way is essential to understand: why maize production and consumption are important into small farmers households in developing countries, and their differences between industrialized and developing countries as a global review, discussed into Chapter 2; what is the maize technology and their differences between Traditional Varieties (TV) and Modern Varieties (MV), explained in Chapter 3; is obligatory to describe small-scale farmers characteristics, income and activities diversification, education, etc., into Chapter 4; then, briefly to look back at the agricultural policy reform in Mexico, the environmental policy are briefly explained, and analysis different programs of seeds diffusion, studied in Chapter 5; The place of the research, briefly explains why the 12 villages were studied and surveyed, the characteristics are shows into the Chapter 6; what is the meaning of adoption and diffusion of technology theory, and a briefly review of different works, discussed in the Chapter 7; Finally, attempt to develop an econometric method that meets small farmer characteristics and their complexity in the uses of their set of seeds throughout time, space and quantity dimensions, developed in Chapter 8. The *Tesina* ends with the conclusions in the Chapter 9.

2. The Maize

Maize is one of the three cereals that dominate the world grain economy; the others are wheat and rice[11] (FAO, 2004b). In industrialized countries, maize ranks secondly compared to wheat in area planted and production. In developing countries, where most of the world's rice production is concentrated, maize ranks thirdly behind rice and wheat (Morris, 1998b).

Unlike wheat and rice, which are mainly consumed as human food, maize is a multipurpose crop that can be eaten by human, fed to animals, or used as raw input industry. Most maize produced in industrialized countries is used as animal feed or for industrial purposes, but maize remains as an important food staple in many developing regions, especially sub-Saharan Africa and Central America, where it is frequently the mainstay of humans' diets.

Considering the wide geographical dispersion of maize, it is not surprising that the productivity of maize production systems varies from place to place and among groups of producers. Although productivity can be expressed in different ways, one commonly used measured is grain yield per unit land area. With good management, commercial maize grain yields often reach 10 tons per hectare (t/ha) or more in favorable production environments such as the "corn belts" of the United States and Western Europe. In contrast, subsistence farmers in marginal areas in Central America, sub-Saharan Africa, and Asia frequently harvest 0.5 t/ha or less of grain from their maize plots (Morris, 1998b). The variability in yields can be attributed to environmental, technological, and institutional factors that determine the physical potential of the crop, influence the availability of yield-enhancing technology, and affect economic incentives to adopt improved technology.

2.1 Why the Maize?

No other cereal can be used in as many ways as maize. Virtually every part of the maize plant has economic value. The grain can be consumed as human food, fermented to produce a wide range of foods and beverages [in Mexico, for instance, a great variety of

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[11] Rice is central to food security in the world. It is the main source of calorie intake for about half of the world's population and the predominant staple food for 34 countries in Asia, Latin America and Africa. In several Asian countries people depend on rice for more than two thirds of the calories and 60 percent of the protein in their diets (FAO, 2004b)

tortillas[12] exists, and there are more than 600 different food preparations involving maize, many of these preparations require different types of maize (SEP, 2002)], fed to livestock, and used as an industrial input in the production of starch, oil, sugar, protein, cellulose and ethyl alcohol. The leaves, stalks, and tassels can be fed to livestock, either green (in the form of fodder or silage) or dried (in the form of stover). Even the roots can be used for mulching, incorporated into the soil to improve the physical structure, or dried and burned as fuel (Morris, 2002).

In view of the multiples uses, it is not surprising that the maize varieties being grown today include literally thousands of distinct cultivars with different combinations of consumption traits (ear size and shape; grain size, shape, color, texture, smell, and taste; grain processing, storage, and cooking quality; endosperm oil or starch content; husk quality) (Morris, 2002). Although maize is not the only crop to feature a lot of genetic diversity[13], what distinguishes maize from most other crops is the extent to which genetic diversity is actively managed at thousand levels. In most developing countries where maize is an important crop, it is common to find the same household growing three, four, and sometimes even more distinct maize varieties, each carefully selected to satisfy special food, feed, or industrial use.

As seed: of all the inputs used in agriculture, none has the ability to affect productivity as much as seed. A seed is a living organism that carries the genetic properties of plants. These genetic properties place an upper limit on yield potential and influence the productivity of other inputs by determining the ability of plants to convert sunlight, water, air, soil, and other nutrients into biomass (Pandey, 1998; Morris, 1998c). Because plants vary in terms of their ability to perform this conversion, seed choice is critically important in agriculture.

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[12] Thin round cakes made from ground grain and water, cooked on a heated clay or metal surface.

[13] Diversity exists in wild species and in crops. It has its origin in the history of each species and the management by farmer in the case of crops. Diversity is expressed through many traits and has its base in the variation of the many genes (and alleles) that are involved in their expression. The origin of this variation is mutations, which occur constantly and naturally and can accumulate in the genome. When these mutations affect the expression of recognized traits, selection helps (increase or decrease) their frequency in the populations. Mutations migrate from one population to another, promoting diversity within populations (Bellon and Berthaud, forthcoming in World-Development)

2.1.1 Why the Maize is Important in Mexico?

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 for exceeding that of a simple commodity. Maize *Tortillas* are offered as sacraments; kernels are used in ritual divination; maize is respectfully considered as a sapient being. So, growing a maize crop is evidence that the farmer is committed to the rural community, its connection to the past, and its values (Brush, 2004). The binding connection of maize and rural community is evident in indigenous art and archeology since before the European arrival in the New World. And maize is very important in the diets of Mexican population, particularly in the rural areas and among the poor. The level of consumption and the ways maize is prepared for its consumption are very different from the way that maize is used and consumed in developing countries (SEP, 2002).

2.2 Maize Production

Maize is found on all five continents in a range of climates, elevations, precipitation regimens, and soil types. It is grown in favorable production zones characterized by adequate and reliable rainfall, moderate temperatures, and naturally fertile soils, as well as in unfavorable or marginal productions zones characterized by moisture stress, temperature extremes, and soil nutrient imbalances. This variability is important, because the characteristics of each environment, type of germplasm and management practices are likely to be suitable there.

Reflecting its ability to adapt to a wide range of production environments, maize is cultivated at latitudes ranging from the equator to approximately 50° North and South, at altitudes ranging from sea level to over 3,000 meters elevation (Morris, 2002), under temperatures ranging from extremely cool to very hot, under moisture regimes ranging from extremely wet to semi-arid, on terrain ranging from completely flat to precipitously steep and in many different type of soil.

2.2.1 Maize Production: Industrialized Countries.

In most industrialized countries in which maize is an important commercial crop, production technologies reflect the highly specialized, input-intensive nature of modern science-based agriculture. Whether maize is grown for use on the farm as an input into the livestock production enterprise or for sale as a cash crop, the scale of production is generally large: The typical U. S. maize farmer plants 75-100 ha and the typical European farmer approximately 50% of 75-100 ha (Morris, 1998b). In industrialized countries most maize is grown under rain-fed conditions (the crop's relatively low value makes irrigation uneconomical) and maize production is generally concentrated in zones of abundant rainfall and fertile soils. Maize in industrialized countries is invariably mono-cropped, and it is most frequently grown every year on the same land or alternated with soybeans. Land preparation, planting, cultivation, and harvesting operations are completely mechanized, reflecting the generally high cost of farm labor relative to machinery. Virtually 100% of the area planted to maize is under high-yielding varieties (hybrids), and use of chemical fertilizer, herbicides, and pesticides is extensive (FAO, 2004a).

2.2.2 Maize Production: Developing Countries.

Maize production technology in developing countries is more variable, reflecting not only the wide range of production environments in which maize is grown but also disparities in farmer knowledge access to resources.

Throughout most of Mexico and Central America, as well as in many localized regions within some of the Andean Zone countries of South America, maize is an important food staple that is produced and consumed by a large part of the rural population. Except in a relatively small commercial farming sector, most maize production systems in these countries are characterized by their small scale, complexity, subsistence orientation, and heavy reliance on animal traction, an especially human labor (Morris, 1998b). Maize is often grown in association with beans, squash, peppers, cassava, and other food crops destined for home consumption, and many farmers use little or no chemical fertilizer or pesticides, this practice is known by the name of *Milpa* system (Brush, 2004). Use of improved varieties is often limited, either because farmers lack access to reliable sources of affordable seed or because they prefer to grow traditional maize varieties developed to meet specific food and feed requirements. Lacking the resources, technical knowledge, or both to acquire and manage modern inputs, many farmers respond to the increased demand for maize by expanding the area planted rather than increasing yields through intensifying their use of purchased inputs. Although maize production has generally kept pace with population growth (with notable exception of Mexico), it is not clear that current levels of production are sustainable over the long term, since farmers have been forced to shift production into even more marginal areas, especially hillside areas susceptible to erosion.

Elsewhere in Latin America, the picture is different. In southern Brazil, Argentina, and Chile, maize is primarily a cash crop grown by large-scale commercial producers using extensive mechanization and (where profitable) high levels of purchases inputs. Many of the maize production environments found in these countries feature a temperate climate, so growers have been directly to adopt commercial hybrids and improved management practices imported from North America and Europe.

In Africa, maize is a relative newcomer among staple food crops: It arrived in the XV century in the holds of Portuguese ships. With a few notable exceptions (e.g. parts of Ghana, Togo, Benin, Côte d'Ivoire, and Nigeria), maize never became a leading crop in the lowland tropical environments of West Africa-in part because many of the varieties introduced directly from North America performed poorly in the hot, humid conditions and proved susceptible to local diseases and in part because alternative starchy foods were readily available (Morris, 1998b). But, in eastern and southern Africa, maize became the dominant food crop and the mainstay of rural diets, not only because it was well suited to the region's drier, cooler production environments also because colonial governments actively promoted it.

Africa's maize production systems vary widely in scale and productivity. At one end of the range can be found large numbers of peasant farmers who cultivate small plots of maize using family labor or animal traction as the principal source of power. Many of these small-scale farmers grow traditional varieties, applying little or no fertilizer. Yields are generally low, averaging around 2 t/ha or less, and weather-induced crop failures are common. These small-scale producers account for around 70% of all the maize produced in Africa (and probably more than 90% if the Republic of South Africa is excluded) (Morris, 1998b). At the other end of the range are a relatively small number of large-scale commercial farmers who grow maize for sale as a food crop or for use on the farm to feed livestock. The large-scale commercial farms, which are concentrated in eastern and especially southern Africa, are often former settler estates established during the colonial period. The production technologies used by Africa's commercial maize farmers, which are concentrated in eastern and especially southern Africa, are often former settler estates established during the colonial period. The production technologies used by Africa's commercial maize farmers are more similar to those found in industrialized countries: Land preparation, planting, and cultivation operations are generally mechanized; use of improved inputs is extensive; and average yields are high (although even on commercial farms yields are characterized by considerable year-to-year variability) (Morris, 1998b).

Asia differs from other regions in the developing world so that most maize in Asia is produced to feed livestock (significant exceptions include parts of India, Nepal, southern China, Indonesia, and the Philippines, where people are the primary consumers of maize). Maize production statistics for Asia are dominated by the statistics for China, whose maize crop is the largest in the developing world and the second largest overall after that of the United States. Because most of China's maize crop is produced in the northern part of the country where a pleasant climate prevails, Chinese breeders have been able to make extensive use of improved germplasm imported from the United States and Western Europe. Hybrids developed with the help of imported germplasm have been promoted successfully through China's major maize-producing zones, where hybrid adoption levels currently rival those found in the U. S. Corn Belt. With the help of government polices designed to encourage the use of fertilizer and other productivity-enhancing inputs, China's national average maize yields have grown rapidly to their current levels of around 5.0 t/ha, double the average level for all developing countries (Morris, 1998b; FAO, 2004b).

Outside China, Asian maize production systems more closely resemble those found in sub-Sahara Africa and Central America: Farms are small, use of improved germplasm and purchased inputs are modest, and yields are generally low. In India, most maize is grown by smallholders to meet household consumption requirements, although commercial production of feed maize has increased in recent years in response to urban consumers' increasing demand for livestock products. In Vietnam, the Philippines, and Thailand, the bulk of the maize crop is now fed to livestock, especially pigs and poultry (Morris, 1998b).

2.2.3 Maize Production: in Small-scale Farmers

The maize agricultural system of small-scale subsistence oriented farmers can be characterized as open genetic system. In these systems, multiple maize populations coexist (Bellon, 1994). Most seed is saved from the previous harvest (Morris, M.L., and M.A. López Pereira., 1999), though some seed may also be acquired from other farmers or even commercial source. Farmer may mix seed from different sources if there is lack of sufficient seeds or they wish to experiment with or expressly modify maize populations (Perales, 2003b). Farmers may incorporate improved varieties and expose them to their conditions and management, fostering the local adaptation, a process known as "*creolization*[14]" or "*hybridization*" (Bellon, 2001). New alleles are introduced and, through recombination, incorporated into new genetic backgrounds. These practice and conditions are conductive to gene flow and the development of maize populations with a long life that extends over many generations (M.R. Bellon and J. Berthaud personal communication).

Perales *et. al.* (2005) reveals several common management features on Mexican maize agriculture:

- Persistence of local maize types.
- Relative dominance of one or two types at both the household and community levels.
- Cultivation of minor varieties, which contribute minimally to overall production.
- High substitutability of different maize types for *tortillas*, the basic staple.
- Selection of seed from harvest ears, apparently based on an ideotype of local maize.
- Small but consistent acquisition of new seed from neighbors and more distant sources.

Finally, research on the maize systems of Mexico has shown them to be opened but conservative in terms of seed management and farmer selection (Perales, 2005).

The figure 1: shows the areas with relatively high concentrations of farm saved maize seed. Red-maize-production countries where farm-saved seed is planted to more than 50% of the area; green-maize-production countries where farm-saved seed is planted to less than 50% of the area; blue no data available. Farm-saved seed includes landraces, farmer-bred varieties, and advanced generations of modern varieties. Source: International Plant Genetic Resources Institute (IPGRI) (<www.ipgri.cigar.org>, consult May 2005).

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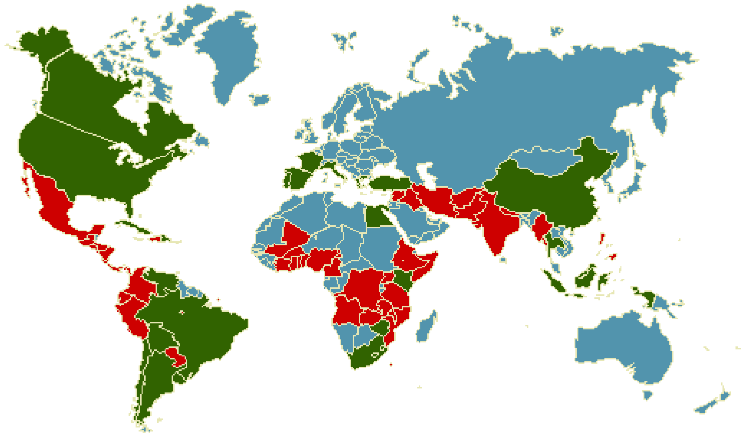
[14] Strictly speaking, the adoption of improved maize varieties has been limited in Mexico, but there is increasing evidence that though their breeding practices small-scale subsistence farmers have incorporated improved varieties into their farming systems. By exposing improved varieties to their conditions and management, continually selecting seed of these varieties for replanting, and some cases promoting their hybridization with landraces either by design or accident farmers produce "creolized" varieties. Creolized varieties are appreciated because they combine the advantages of improved varieties and landraces (Bellon & Barthaud Forthcoming in World Development).

Figure 1: Area of relatively low use of modern varieties



Source: www.ipgri.cgiar.org (consult may 2005).

It should be pointed out that farmers' Traditional Varieties are not antique vases held in a museum. They are constantly changing under both human and natural selections, and gene flow plays a key role in their evolution. The incorporation the foreign germplasm particularly from improved varieties or other related, into traditional varieties has been common and does not seem to be viewed as negative by small-farmers, and has been part of the open genetic system that characterizes maize in Mexico (Bellon M.R., per. com.). In many instances farmers consider it positive and they actively try to mix seed from the local materials with foreign varieties to improve the former (Perales, 2003b).

2.2.4 Maize Production: in Mexico

In Mexico, maize has a great cultural significance for small-farmers. These farmers are both producers and consumers of the crop and heirs to those that domesticate the crop several thousands of years ago. Hence, there is long history of co-evolution between local human populations and maize (SEP, 2002). The diversity of maize types that observe in Mexico is related to the constant divergent selection that farmers continue to exert on maize populations to meet their cultural and agronomic needs (J. Berthaud personal communication). This cultural significance is evidence by the diversity of maize types cultivated, as well as the wealth of dishes prepared from maize and the rituals and beliefs associated with its cultivation and preparation (SEP, 2002). Farmers talk about maize with much affection and respect. Clearly, maize for small-farmers has significance beyond that a commodity produced simply profit (Dagoberto Flores personal communication).

In Mexico, the polarization and large disparities in the configuration of cultural, socio-economic, and technological elements characterized contemporary Mexican agriculture. Maize production across different regions and social groups shows the contrast between industrialized production using advanced technology and MV, and subsistence production relaying on elements of pre-Hispanic technology and TV in shifting cultivation. 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 socioeconomic groups. S. Brush (2004) suggest 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 three categories are found across different maize producing regions and different according to farm size, the production objective; source of maize seed, use of purchased inputs such fertilizer and pesticides, and access to irrigation.

In Mexico as one 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, 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* (Brush, 2004). 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 Mexican cuisine (SEP, 2002).

To day approximately 7.5 million hectares are planted in Mexico, and the crop is the most widely cultivated in Mexico (Aquino, 1998). Over 60% of the cultivated, rain fed area is devoted in maize. And the non-commercial and semi-commercial sectors comprise 60% of the production units, utilize 33% of the maize area, and produce 37% of the national production of the grain (Brush, 2004). The 20% national area planted in improved maize (Open Pollinated Varieties and Hybrid) is concentrated in the commercial sector, although this sector also relies on local varieties or Traditional Varieties that are advanced generations of modern varieties managed as landraces "*acriolladas*" (Morris, M.L., and M.A.

López Pereira., 1999; Bellon, 2003). Small-farmers also attempt to acquire traits of MV by crossing them with TV (Perales, 2003b). Seed selection[15] for planting is non-commercial and semi-commercial farm largely done post-harvest, and the selection process is often extended by practice of adding seed during food preparation (Rice, 1998).

Finally despite the availability of improved maize varieties over the last 40 years and repeated Government programs to encourage their use, today improved varieties (Open Pollinated Varieties and Hybrid) are planted in only about one-fifth of the total maize area of the country (Aquino, 1998; Morris, M.L., and M.A. López Pereira., 1999; Bellon, 2003). Most of this area is located in the commercial production zones of central and northwestern Mexico. Hence about four-fifth of the area under maize are planted to landraces or recycled improved varieties.

2.3 Maize Consumption

The maize grain types: numerous cycles of selection by farmers and (more recently) within scientific breeding programs have led to a proliferation of maize grain types, which differ widely in size, shape, color, hardness, smell, taste, easy of processing, storage quality, and other characteristics. In international markets, grain types are commonly characterized in terms of two main traits: color and hardness.

All types of maize, regardless of their color, are genetically and biologically similar, but the presence or absence of certain pigments in the cover of the kernel (pericarp) can produce a vivid spectrum of grain colors. Approximately 85% of the global maize crop consists of white-grained materials, and the remainder consists of red-, blue-, purple-, or black-grained materials (Morris, 1998b).

M. Morris (1998b) to point out that depending on the composition of the kernel, the hardness of maize grain can vary considerably. In flint maizes, most of the kernel is composed of hard starches, giving the kernel a rounded, slightly shiny surface. In dent maizes, the inside of the kernel is composed of soft starches that contract as the dry, giving the kernel a concave, opaque surface. Approximately 80% of the global maize crop consists of dent or semident materials; and additional 15% consists of flint or semiflint materials.

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[15] 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 (Brush, 2004).

The remaining 5% is composed of specialized grain types, such as the floury maizes of the Andean Zone and the waxy maizes originating from China.

2.3.1 Uses of Maize: Industrialized Countries.

In most industrialized countries, maize has little significance as human food. Over three-quarters of the maize produced in these countries is fed to animals, principally cattle, hogs, and poultry; the remainder is used mainly as an input into a number of extractive industries. Because of its high starch and low fiber content, maize grain is an extremely concentrated energy source. Readily consumed by animals, it gives the highest conversion among all major cereals of dry matter to meat, milk, and eggs.

In the United States and Europe, producers for use on their own farms to feed cattle or hogs retain approximately half of the maize grain crop. The remaining half is sold to the feed industry as an input into maize-based feed rations. Feed mills combine whole or cracked shelled grain with various sources of protein, vitamins, and minerals into specially formulated rations designed to meet the specific nutritional requirements of different animal species at particular stages of their growth cycles (Morris, 1998b). The composition of these feed rations is determined based on least-cost pricing principles, so maize use fluctuates depending on its relative price and alternate source of starch, protein, and other ingredients. Because maize is relatively inexpensive compared to readily available substitutes, however, demand for maize as a feed ingredient is fairly stable.

In addition to the maize that is fed to animals in the form of grain, a significant portion of the crop in industrialized countries is fed to animals as forage. Forage uses of maize include fodder (leaves and stalks, tassels, husks), stover (dried stalks minus the ears), and silage (entire plant chopped and fermented). Between 10% and 30% of the maize planted in the United States and Europe is used as forage, primarily to feed beef and dairy cattle (Morris, 1998b).

2.3.2 Uses of Maize: Developing Countries.

In developing countries, maize is used primarily as human food and as animal feed. The relative importance of these two uses varies by region and country.

In Mexico, Central America, and the Andean Zone of Latin America, most maize is consumed directly by humans, frequently in the form of *tortillas* (thin round cakes made from ground grain and water, cooked on a heated clay or metal surface). Other common forms of preparation include toasted or boiled green eras, as well as various baked or fried dishes made from grain. Countries in which annual per capita maize consumption is particularly high include Mexico (127 kg), Guatemala (103 kg), Honduras (98 kg), El Salvador (93 kg), Venezuela (68 kg), and Nicaragua (56 kg) (Morris, 1998b).

Not unexpectedly, considering the central role of maize in human diets, Latin American consumers readily distinguish among a wide range of maize varieties on the basis of physical attributes such as appearance, texture, taste, smell, processing quality, cooking quality, and storage quality. Countless cycles of selection by farmers have yielded literally thousands of local varieties distinguished by their unique characteristics. By and large, Latin American maize consumers strongly prefer white-grained materials. Since little difference usually exists in the digestibility or nutrition value of white and yellow maize, this preference is apparently related to the appearance and taste of dishes prepared from white maize. The preference for white maize may also stem from historical experience: When imports have been necessary to meet local production shortfalls, many countries have imported yellow feed grain whose consumption qualities have frequently been unsatisfactory.

Throughout large areas of sub-Saharan Africa, particularly eastern and southern Africa, maize is consumed directly as human food-most frequently in the form of porridge, soup, or gruel prepared from ground grain. Roasted or boiled green ears may also be consumed. In some parts of western and central Africa, grain-and-water mixtures are fermented prior to cooking. People directly consume about 85% of the maize produced in sub-Saharan Africa; only a small proportion of the crop is fed to animals, generally poultry. As in Latin America, throughout most of sub-Saharan Africa consumers strongly prefer white-grained materials. Once again, the source of this preference seems to be historical and cultural; it does not appear to come from any association between grain color and digestibility or nutritional quality. Annual per capita maize consumption levels can be extremely high, especially in Malawi (137 kg), Zambia (113 kg), South Africa (94 kg), Kenya (93 kg), Zimbabwe (89 kg), and Lesotho (87 kg) (Morris, 1998b).

In Asia, where the principal food staple is often rice, maize rarely forms the mainstay of the human diet and is generally used to feed livestock. Depending on the type of livestock, as well as the availability of alternative feed source, maize may be fed to animals as either forage or grain. Throughout most of East and Southeast Asia, where meat consumption is relatively high, producers retain much of the maize crop to use as an input into backyard hog and poultry operations. In South Asia, where meat consumption is much lower, maize is most commonly used as a source of fodder for cattle (Morris, 1998b).

Sixty percent of the maize producers in Mexico are in the non-commercial and semi-commercial sectors (as shown in the section: *2.2.4 Maize Production in Mexico*), and these producers, the crop has a value well beyond being a marketable commodity. These sectors contrast to the commercial sector in the 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 the farm household in unpredictable and often threatening physical and social environments. Producing maize for home consumption means that the farmers in the non-commercial and semi-commercial sectors are protected to some degree for the uncertainty of an economy that is often unfavorable because of frequent unemployed, the necessity to work away from home, inflation, and unstable prices for other commodities. Life in the large national economy is perceived as struggle and prejudiced against the rural poor, and producing a maize crop, albeit inadequate, provides a measure of security (Brush, 2004).

Once again, the majority of the maize producers in Mexico are small-scale subsistence farmers. The country's basic grains are produced on small farms that cannot produce enough food to satisfy the basic nutritional needs of a typical family (5-6 persons). The numerical importance of these groups of farmers, their precarious nutritional situation, and their high rate of demographic growth demand a long-term effort aimed at improving their productivity and income. The incorporation of new technologies into existing maize production systems should help achieve these goals (Sain, 1999).

3. Maize Technology

This Chapter provides a non-technical introduction to the maize technology and theory of plant breeding. First, a modest explanation of the origins, morphology, physiology, and genetics of the maize plant are reviewed. Second, conventional breeding methods used to improve the genetic potential of the crop are described. Third, in a few words description between Traditional Varieties (TV), Open Pollinated Varieties (OPV) and Hybrid Varieties (H) are discussed.

The Modern Varieties (Open Pollinated and Hybrid Varieties), fertilizers and pesticides are response to increased demand for food, decreasing land area for farming, declining percentage of farmers, and improved means of distribution over larger areas. The ability of population growth and spatial integration to transform farming systems is evident in the rapid diffusion of modern cultivars (Brush, 1995).

Developing biotechnology in ways that contribute to the sustainable development of agriculture can help significantly in meeting the food and livelihoods needs of a growing population. The study of genomics and molecular markers, for example, can facilitate breeding and conservation programs and provide new tools in the fight against plant and animals diseases (FAO, 2004a). FAO recognizes the need for a balanced and comprehensive approach to biotechnological development, taking into consideration the opportunities and risk[16].

Biotechnology can overcome production constraints that are more difficult or intractable with conventional breeding programs and provide farmers with diseases-free planting materials. It can create crops that resist pests and diseases, replacing toxic chemicals that harm the environment and human health, and it can provide diagnostic tools and vaccines that help control devastating animal diseases. It can improve the nutritional quality of staple foods such as rice and cassava and create new products for health and industrial uses (FAO, 2004a).

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[16] Risk is an integral part of everyday life. No activity is without risk. In some cases inaction also entails risk. Agriculture in any from poses risk to farmers, consumers, and the environment. Risk analysis consists of three steps: risk assessment, risk management and risk communication (FAO, 2004a).

But Biotechnology is not a panacea. It cannot overcome the gaps in infrastructure, markets breeding capacity, input delivery systems and extension services that hinder all efforts to promote agricultural growth in poor, remote areas. Some of these challenges may be more difficult for biotechnology than for other agricultural technologies, but others may be less difficult. Technologies that are embodied in a seed, such as transgenic insect resistance, may be easier for small-scale, resource-poor farmers to use than more complicated crop technologies that require other inputs complex management strategies. On the other hand, some biotechnology packages, particularly in the livestock and fisheries areas, require a certain institutional and managerial environment to function properly and thus may no be effective for resource-poor smallholders (FAO, 2004a).

3.1 The Maize Plant

Maize (*Zea mays L.*) belongs to the family *Gramineae*, subfamily *Panicoideae*, and tribe *Maydeae*. The tribe *Maydeae* includes seven distinct genera: *Zea* and *Tripsacum* (native to the Western Hemisphere), as well as *Coix*, *Chionachne*, *Sclerchne*, *Polytoca*, and *Trilobachne* (native to Asia) (Pandey, 1998).

3.1.1 Origin and Evolution

Archaeological and botanical evidence suggest that maize originated in southern Mexico or northern Guatemala between 5,000 and 10,000 years ago (Pandey, 1998). Although the geographical origin of the crop is known, its evolutionary line of descent remains something of mystery. Modern maize may have evolved from a now extinct ancestor, from a cross between *Coix* and *Sorghum* from *teosinte* or *Tripsacum.* In parts of Mexico and Guatemala, maize and *teosinte* coexist, hybridize easily, and produce fertile seed, suggesting that *teosinte* may have played a major role in the evolution of the present-day maize plant.

3.1.2 Genetic Diversity

Largely because of the manner in which it reproduces, maize is a highly heterogeneous and heterozygous species. Migration, isolation, mutation, and hybridization have contributed to a large amount of genetic variability in modern maize cultivars. To facilitate classification of this genetic variability, permit developed the concept of *race*, which is defined as: a group of related plants with enough characteristics in common to permit their recognition as a group (Pandey, 1998). Approximately 130 distinct races of maize have been described in the

Western Hemisphere, the majority of which are found in Mexico[17], Central America and South America. Many races show strong adaptation to particular agro ecological conditions.

The races of maize contain considerable genetic variability for many of the traits considered important for breeding purposes. Most maize races are no directly useful for breeding, however, as they lack the morphological and agronomic characteristics required for commercial cultivation. Maize breeders have used some maize races directly or in crosses with other germplasm to develop and improve populations and gene pools that can serve as sources of superior Open Pollinated Varieties (OPV), inbred lines, and Hybrids (Pandey, 1998).

3.1.3 Biology and Physiology

The maize plant's ability to convert nutrients (air, sunlight, water, soil) into biomass is little short to remarkable. In approximately 120 days, a single maize seed weighing about 3 grams can develop into a plant up to 6 meters (m) tall, bearing as many as 1,000 seeds or more (Pandey, 1998). Maize is a monoecious plant, with male (tassel) and female (ear) flowers on the same plant. The tassel is located at the top of the stem, and one or more ears are located about midway down. This spatial arrangement of the male and female flowers facilitates both selfing (pollination of the female flower with the pollen from the same plant).

3.1.4 Reproduction

Reproduction in maize is initiated when pollen shed from a tassel fertilizes ovules located in the ear. Each tassel on a mature maize plant can produce up to 10 million male gametes (pollen grains). These pollen grains are enclosed in anthers, which open a few days before the silks (stigmas) emerge on the ears. Within minutes of landing on a silk, a pollen grain germinates, sending a pollen tube down along the stigma to the ovary, where fertilization is completed within 24 hours. A single ear can produce up to 1,000 female gametes (ovules), with each gamete eventually producing a viable seed. Although a maize plant may be shedding pollen when its stigmas (silks) emerge, normally more than 97% of the seeds produced by any given plant result from pollination with pollen from other plan (Pandey, 1998). This spatial arrangement of the flowers facilitates both selfing (pollination of the

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[17] In Mexico 49 maize "races" have been identified (Bellon *et. al.* forthcoming: The World Development).

female flower with pollen from the same plant) and crossing (pollination of the female flower with the pollen from a different plant) (Morris, 2002).

The ability to open-pollinate distinguishes maize from other leading cereals such as wheat and rice, which are self-pollinating. When self-pollinating crops reproduce, the pollen used to fertilize a given ovary almost always comes from the same plant, with the result that each generation of plants retains the essential genetic and physiological identity of the preceding generation. By contrast, when maize reproduces, genetic material is exchanged between neighboring plants, with the result that unless pollination is carefully controlled, all of the maize plants in a given field will tend to differ from the preceding generation and from each other (Morris, 2002). In fact, Maize is a cross-pollinating crop, rice and wheat are self-pollinating crops, and potatoes are generally clonally propagated, which means that genetic migration and recombination occur at a much lower in rice, wheat, and potatoes than in maize (Bellon, 2004).

3.1.5 Genes and Genetic Expression

Maize is a diploid organism in which genes are regularly transmitted from parents to their progeny. Genes, made up of complex sequences of paired bases (nucleotides) located on chromosomes, are units of inheritance. A gene may have two or more forms (alleles) that provide alternatives of inheritance (Pandey, 1998). Molecular and other techniques have been used to locate several thousand genes in maize, many of which are responsible for economically important traits.

When genes act singly or in combination with a few other genes and the environment has little or no influence on their action, the resulting trait is termed qualitative. Many genes (or gene combinations) have been identified that qualitative alter plant morphology without significantly affecting the economic value of the plant (e.g. changing the color, orientation, and texture of the tassel and leaves). Other genes (or gene combinations) have been identified that can qualitatively alter plant morphology in ways that have significant economic implications (e.g. modifying the grain to enhance sugar content, protein quality, and starch content) (Pandey, 1998).

3.1.6 Maize Production Environments

No universally recognized system exists for classifying maize production environments. The closest thing to a standardized classification system has been developed by International Maize and Wheat Improvement Center (CIMMYT[18]), which holds the global mandate for maize germplasm improvement in developing countries. CIMMYT recognizes four major maize production environments, known as mega-environments; (1) lowland tropics; (2) subtropics/mid-altitude zones; (3) tropical highlands, and (4) temperate zones (Morris, M.L., and M.A. López Pereira., 1999). These mega-environments, which are defined primarily in terms of climatic factors (e.g., mean temperature during the maize growing season, elevation above sea level, day length), theoretically are characterized by their relative within-class uniformity. Since the growth habits of maize plants are influenced by complex interactions among many different climatic factors, however, it is not always clear exactly where one mega-environment ends and the next begins.

Once explained the maize plant physiology, for simplification there are three general categories of materials: (1) cultivars grown from farm-saved seed (including landraces or farmers' traditional varieties); (2) newer Open Pollinated Varieties (OPV) grown from commercial seed or from recycled seed emanating from recently-purchase commercial seed; and (3) Hybrid Varieties grown from newly-purchased commercial seed.

The Modern Varieties (MV) are the products of scientific maize breeding programs, whether Open Pollinated Varieties or Hybrid, are referred to as MV, reflecting the fact that their characteristics have systematically been altered in ways that bring economic benefits to those who grown them. Although use of the term *Modern* is appropriate in this context, an unfortunate consequence of the convention is that the Traditional Varieties grown by farmers often end up being consider *Non-Modern*. This clearly incorrect, Landraces have been subject to numerous cycles of improvement at the hands of farmers, many of whom are skilled at identifying superior germplasm and expert at selecting individual plants that embody desired traits.

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[18] The international Maize and Wheat Improvement Center (know by its Spanish acronym) is committed to providing resources-poor farmers in developing countries with the best options for implementing sustainable maize and wheat systems.

Transgenic maize, 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. 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 (Brush, 2004).

In addition to implying that local varieties are unimproved, use of the term *improved germplasm* to refer only materials produced by formal breeding programs can have another unfortunate consequence. Varieties and Hybrids undergo continual genetic change in farmers' fields. In the case of varieties and hybrids developed by formal breeding programs, this phenomenon is often referred to as "genetic deterioration" or "genetic depreciation," and the process is frequently described as one in which improved materials became "contaminated" by exposure to external sources of pollen. Use of such negative terms is misleading and may in fact incorrectly characterized what is actually happening. Although genetic changes is undesirable when farmers would prefer to preserve the characteristics of the original germplasm, in many instances genetic change occurs as cultivars become better adapted to local production conditions and/or consumption preferences. In other words, what plant breeders sometimes refer to with the pejorative term "genetic deterioration" may be quite desirable from farmers' point of view. For this reason, some authors use the more positive term "rustication" to describe the process by which materials produced by formal breeding programs change in the hands of the farmers.

In this *Tesina*, the term Modern Varieties refers to the Open Pollinated Varieties and Hybrids produced by formal plant breeding programs. This usage is not meant to imply that local varieties are in any sense unimproved. Similarly, we try to avoid use of terms such as "contamination" and "genetic depreciation" in describing the genetic changes observed in farmers' fields.

3.2 Traditional Varieties

The concept of Traditional Varieties (TV) or Landrace is complex, and here use this term for a locally grown maize population that a farmer cultivates as a seed lot. A seed lot is defined as: "…all kernels of a specific type of maize selected by a farmer and sown during a cropping season to reproduce that particular maize type" (Brush, 1995). Traditional Varieties or Landrace is a term that is widely used by Mexican farmers to refer to their local maize types. TV's may be consider as native, although, as with other crops, continual change over time is part of maize evolution (Bellon, 1994; Perales, 2003a). Landrace means seed that is adapted to local conditions rather than seed that are autochthonous in farmers' crop populations.

3.3 Development Open Pollinated Varieties

Open Pollinated Varieties (OPV), reflecting the fact that their characteristics have systematically been altered in ways that bring economic benefits to those who grown them. Improved OPV are populations that have attained genetic equilibrium, so that random cross-pollination among plants of the same improved OPV should not affect the genetic and genotypic frequencies. In theory, therefore, if an improved OPV is properly isolated, seed can be recycled for many years without undergoing visible changes. In practice, however, plan populations (and farmers' seed lots) are not infinitely large, so that rare alleles may be lost through time. Furthermore, farmers often cannot completely isolate their maize production plots, resulting in cross-pollination from other varieties growing in adjacent fields. Because these various sources of genetic change are difficult to control, most improved OPV, likely many landraces, turn out to be genetically diverse and constantly changing (Pandey, 1998).

3.4 Development Hybrids

Strictly speaking, the term *hybrid* refers to any plant produced from genetically distinct parents. Maize hybrids are produced by crossing some combinations of genetically distinct parents. Conventional hybrids are produced using two or more inbred lines as parents, while non-conventional hybrid are produced from parents at least one of which is not inbred line (Table 1). *Conventional Hybrids* including single crosses formed by crossing two inbred lines (A x B), the three-way crosses formed by crossing an inbred line with a single cross [(A x B) x C]. Examples of *Non-Conventional* hybrids include varietal crosses formed by crossing two OPV and top crosses formed by crossing an inbred line with an OPV.

Table 1. Types of maize hybrids, showing genetic composition of parents

Conventional hybrid	
Single cross	Inbred line x inbred line
Three way cross	Single cross hybrid x inbred line
Double cross	Single cross hybrid x single cross hybrid
Non-conventional hybrid	
Top-cross	Open pollinated variety x inbred line
Double top cross	Single-cross hybrid x open-pollinated variety
Varietal cross	Open pollinated variety x Open pollinated variety

Source: M. Morris *et. al.* (1999a).

Breeding hybrid maize begins with the development of suitable parental material. Inbred lines are typically developed through repeated cycles of controlled self-pollination in which the silks on a given plant are fertilizer-using pollen from the same plant. Inbred lines may also be developed through sib-pollinations in which the silks on a given plant are fertilized using pollen from a sibling plant. The inbred lines (as well as varieties being used as parents, in the case of non-conventional hybrids) then must be evaluated for their ability to make productive crosses. The final step is to produce the best crosses in large quantities for commercialization.

In the view of many professional maize breeders, hybrid maize constitutes “improved germplasm” only in the F1 generation (F1: refers to first generation); advanced-generations hybrids should not be considered improved because the genetic benefits of heterosis are greatly eroded when hybrid seed is recycled. Many research impacts studies implicitly support this view by including in the category “area planted to improved germplasm” only the area planted to F1 seed. But this restrictive view of what constitutes improved germplasm is likely to underestimate the impacts of technology adoption. Seed recycling practices frequently extend to maize hybrids, and planting of advanced-generations hybrids (F2, F3 … F5) is common in many countries. While advanced-generations hybrids may not perform as well as crops grown from F1 seed, in many cases they significantly outperform the variety that farmer was growing previously.

3.5 Biotechnology and Maize

This section provides a non-technical introduction to maize biotechnology, with the objective of examining not only the findings of technology and their application, but also the limitations of biotechnology. As with many fields of modern science, biotechnology is evolving extremely rapidly.

Until recently, efforts to improve maize cultivars were based mostly on conventional plant breeding methods. Today, however, the field of crop improvement research is being rapidly transformed by an array of newly emerging procedures and processes, referred to collectively as *biotechnology*, that promise to provide plant breeders with vastly more efficient techniques for future crop improvement work. Although many potential applications of biotechnology have yet to be realized, the first maize plants produced using biotechnology have already reached the market in some countries. Many other biotechnology-derived plants are currently available, but their commercial release has been delayed, not because of limitation of the technology but because of regulatory barriers enacted out of health and safety concerns.

3.5.1 What is Biotechnology?

In its simplest sense, biotechnology refers to the manipulation of living organisms to alter their characteristics, use them as a component in a larger production process, and produce a desired product (Hoisington, 1998). Traditional biotechnology can be traced back to early history; examples include brewing beer, making cheese, and using other fermentation processes. Today, however, most people think of biotechnology as a new science based on a vastly enhanced understanding of the genetic structure of organisms and their modification at the level of cells and molecules (Hoisington, 1998).

Hoisington (1998) cited The Glossary of Crop Science Terms of the Crop Science Society of America that defines biotechnology research as involving: "the development of products requiring engineering technologies or using technologies such as recombinant deoxyribonucleic acid (DNA) techniques for the modification and improvement of biological systems" pp. 78. In general terms, the importance of modern biotechnology stems from the fact that it offers the novel possibility of shortening lengthy processes of plant and animal breeding and circumventing the conventional barriers of genetic incompatibility. As shown in section *3 Maize Technology*: FAO (2004a) Biotechnology it can create crops that resist pests and diseases, replacing toxic chemicals that harm the environment and human health, and it can provide diagnostic tools and vaccines that help control devastating animal diseases. It can improve the nutritional quality of staple foods such as rice and cassava and create new products for health and industrial uses.

3.5.2 Biotechnology and Maize

Maize has been a primary focus of biotechnology research for several reasons. At the global level, maize is extremely important economically, trailing only wheat and rice in terms of value of production. Furthermore, because commercial maize growers make extensive use of hybrids, private companies have the possibility of capturing benefits from their investments in research through annual seed sales. Primarily for these two reasons, private-sector investment in maize biotechnology research has been enormous (Hoisington, 1998).

In addition to its economic importance, maize has also attracted the attention of biotechnology researchers for technical reasons. Maize is produced and consumed in many industrialized countries that have well-developed, sophisticated research systems, so the basic capacity for biotechnology research on maize is in place. In addition, maize is a natural crop for researchers to work on (Hoisington, 1998). One unusual feature of maize is the presence of transposons-so-called jumping genes that have the ability to move spontaneously from one location to another within the genome, often causing mutations. Transposons constitute powerful tools for identifying, tagging, and ultimately isolating almost any gene of interest (Hoisington, 1998). A number of private and public institutes have also established "gene machines" for maize by taking advantage of large collections of maize plants whose genomes contain transposon-induced mutations that allow easy identification of the function of a given gene sequence. The capacity for these types of analysis is unique to maize and makes it an extremely important species for genetic investigation at all levels.

Applications of biotechnology to maize breeding can be separated into two broad categories: *molecular genetics* and *genetic engineering*. In molecular genetics, the goal is to identify one or more maize genes that confer a desired characteristic on maize plants and to use molecular markers (DNA signposts that are closely associated with specific genes) to identify in successive generations of experimental plants those that possess the gene or genes of interest. Genetic engineering involves inserting into maize plants and obtaining the expression of alien genes; these genes may be obtained from other organisms (plant or animal), or they may even be fashioned synthetically. This capability essentially allows plant breeders to broaden almost without limit the genetic diversity available for maize improvement (Hoisington, 1998).

Most of the genetic engineering work involving maize has concentrated on developing enhanced resistance to insect pest or viruses. Genes for resistance to other pathogens, for tolerance to abiotic stresses such as drought and heat, or for improved grain quality are under development and should be available in a few years (Hoisington, 1998; FAO, 2004a).

3.5.3 Pest-resistant Maize

To date, by far the greatest amount of maize genetic engineering work has focused on improving resistance to insect pests through the insertion of *Bacillus thuringiensis* (*Bt*) genes. The attraction of this work is obvious: If maize varieties and hybrid can be developed that have "natural" resistance to insect pests, farmers could avoid the use of expensive and environmentally damaging chemical pesticides, which in many countries currently represent the only effective means of pest control. Extensive investment in *Bt* research has already begun to produce tangible results, as two transnational seed companies, Novartis and Mycogen, were recently granted commercial permits to sell *Bt* maize in the United States. Concern about possible deleterious environmental impacts of *Bt* maize has led to serious debate and study in agricultural and development circles about its deployment. Genetic engineering work aimed at conferring resistance to other maize pests, particularly viruses and fungal pathogens, is currently underway, but in general this work is far less advanced (Hoisington, 1998; FAO, 2004a).

3.5.4 Herbicide-resistant Maize

Selective herbicides, which destroy weeds without affecting the crop, play an important role in many modern maize production systems in both developing and industrialized countries. Generally, herbicides are cheaper and more effective than mechanical tillage, and since their application does not require that the soil be dislodged, they do not cause erosion (FAO, 2004a). Although the chemical industry has been fairly successful in developing a wide range of selective herbicides targeted at the major weeds of maize, because of their selective nature they are incapable of controlling every weed in every cropping system. In cases where selective herbicides are not completely effective, uses of a more general, nonselective herbicide would be preferable, assuming it would not kill the maize crop.

Most herbicides act by binding to and blocking a critical enzyme. To create resistant varieties, scientist must identify plants that contain a mutant form of the target enzyme. In the past, herbicide-resistance genes were usually identified by exposing vast numbers of experimental plants to herbicide-containing media and searching for resistant individuals. Today, this lengthy and expensive process can be avoided through the use of genetic engineering techniques that allow herbicide-resistance genes to be isolated in other organism (such as bacteria) and inserted into maize plants (Hoisington, 1998; FAO, 2004a).

4. The Socioeconomic Small-farmers Characteristics

This chapter shows different works about socioeconomic small-farmers characteristics, especially exploring income and activities diversification. The studies of Yúnez and Taylor (Yunez, 2001), Abdulai and CroleRees (Abdulai, 2001), Escobal (Escobal, 2001), and Deininger and Olinto (Deininger, 2001) have empirical analysis and results in Less Developing Countries (LDC). Briefly the purpose of this chapter is to analyze the determinants of rural households' decisions to undertake off-farm activities and how small-farmers reduce his risk averse and improve his net income as general characteristics.

Yúnez and Taylor (2001) point out that a fundamental characteristic of rural households is diversification of income. This is especially true in countries at an intermediate level of development such as Mexico, where there are dual agricultural sectors. Rural households in this situation continue to produce staples for home consumption and earn income from other sources (such as production of cash crops and non-farm activities). This is due to their poverty and risk aversion as well as to missing of failed markets for staple foods, factors and credit.

Recent development literature tends to depict income diversification into non-farm sources as favorable development, and education as contributing to diversification by rural households in developing countries. The work of Abdulai and CroleRees (2001) shows that diversification of income sources has been put forward as one of the strategies households employ to minimize household income variability and to ensure a minimum level of income. The authors argue that income diversification refers to the allocation of production assets among different income-generating activities, both on- and off-farm. And the risk-averse households are willing to accept lower income for greater security.

Yúnez and Teylor (2001) show that education and years of schooling affect activities choice of rural households. The results support the argument that the returns to education in rural incomes are high and statistically significant, independent of the level of schooling, in eight villages and 391 households surveyed on 1992-1995 in the rural Mexico. Primary, secondary, and preparatory education has positive effects on income from basic grains for those who produce them, indicating positive returns to schooling in Mexican traditional agriculture. Poverty and persistent market failures make it so that small farmers continue to produce maize and beans for home consumption and to manage risk, incorporating new knowledge through skills acquired in school. The analysis shows that post-primary schooling has positive and significant impacts on commercial farm income.

Abdulai and CroleRees (2001) point out that empirical studies from some countries have supported the hypothesis that income diversification is linked to lower risk. Their work was carried out in Southern Mali. The survey covered the three farming years 1993/94-1995/96 in 15 villages. As well as Yúnez *et. al.* and Abdulai *et. al.* found that given poverty is closely associated with low levels of education and skills, education seems to be a significant factor contributing to the greater ability of wealthy families to diversify. The strong incentive for the poor to diversify was recently observed as farmers in the area increased investments in education. Abdulai argues that the positive and significant impact of education on participation in cash-oriented non-farm activities is consistent with findings from other studies in the region in Southern Mali, Africa.

The lack of capital is certainly a major reason why poorer households have less diversified portfolios, since an average of 42% of the households analyzed indicate that lack of access to credit was a major constraint to their participation in the non-cropping sector (Abdulai, 2001).

Escobal (2001) found that in Peruvian areas, there has been substantial growth over the past decade in household employment outside of own-farming. At present 51% of the net income of rural households comes from these off-farm activities, this suggest that the off-farm activities should certainly no longer be considered "marginal". The reasons households diversify their incomes are several: access to public assets such roads and private assets such as education and credit are an important in diversification. Increasing access will help rural households to amplify their self-employment as well as wage employment in the non-farm sector. Escobal argues that the household problem is to maximize its utility subject to several constrains, among them: a) cash constrain, b) production technologies for own-farming and non-farm self-employment activities; c) exogenous effective prices for cash-products; d) an equilibrium condition for self-sufficiency of farm production; and e) an equilibrium condition for family labor. The reasons to diversify income in rural Peru are various. A large group of farmers compensate for insufficient land, cattle or farm capital with farm wage employment and non-farm activities. Yet another group has sufficient education, skills, credit, and access to roads and electricity to allow them to undertake non-farm wage employment (such as making handicrafts, repairing and renting equipment, and commerce). Many of these non-farm activities are indirectly linked to the farm sector, which is why there are such high levels of participation in the non-farm sector in the more dynamic agricultural areas.

As Escobal's report, Deininger and Olinto (2001) point out that their research for rural households from Colombia found that off-farm employment (wages from agricultural and nonagricultural employment, profits from nonagricultural enterprises, non-earned income, and remittances) contributes a significant share, 45% on average, to household income but that importance of off-farm income and returns to household labor vary over the income distribution. Yúnez *et. al.* found that the eight rural towns are closely linked to the non-rural economy, as 60% of the incomes of their households come from non-farm activities. Deininger *et. al.* found that the imperfections in markets for credit and land, lack of education, and inequalities in asset ownership constitute important barriers to increased specialization. They used data from a survey of about 1,000 rural households. And as well as Yúnez and Taylor (2001), Deininger and Olinto founds that education is an important determinant of specialization: more educated households are less likely to adopt multiple strategies of income generation (Deininger, 2001).

Finally, Abdulai and Huffman (2005) argue, talking about technology adoption, that when a technology is profitable farmers' who have more schooling have a shorter duration of non-adoption. Farmers with considerable education level diversify and adopt more than non-educated farmers.

4.1 The General Small-scale Mexican Farmers' Characteristics.

The mining of "rural" refers to population of less than 5,000. The characteristics of this type of towns reflect the situation of small-scale farmers. This size of population concentrations will be utilized in this *Tesina* as rural. There are other studies that consider different size as rural.

The average size of the maize farms in Mexico is about 2.5 ha. The average of schooling at national rural level is 4.3 years. The share of individuals without education is 22% in rural Mexico. As is the share with only primary education, up to six years of schooling 53% for rural Mexico, and with secondary education, up to 12 years of schooling national rural average is 2% Family size between 5-6 persons (Yunez, 2001).

5. Agricultural Reform in Mexico

The purpose of this chapter is to look back at the agricultural reform in Mexico. The works of Dyer and Yúnez (2003), Yúnez (2003) and Aquino (1998) have been deepened framework of the agricultural policy reform in Mexico and the maize diffusion programs. These works could help to understand the agricultural policy in Mexico.

5.1 Domestic Agriculture Reforms

In 1991, a new government agency, Aid and Services to Agricultural Commercialization (*Apoyos y Servicios a la Comercialización Agropecuaria* –Aserca) was created to take the place of direct government involvement through the National Company of Popular Subsistence (by their Spanish acronym *Conasupo*). In its early years, Aserca dealt only whit wheat and sorghum, it incorporate maize in 1997. Aserca operates an "indifference price" program that does not have nationwide coverage. Instead, every region operates under a specific scheme that consists of a pre-harvest "price agreement" for each crop based on international prices and transport costs. Thus, producers sell their crops to industry at the international price, and the government pays them the difference with the accorded price (Dyer, 2003).

Three years after the establishment of Aserca, a transitional program called Procampo[19] was created. Procampo came into effect during the 1993/1994 winter season—merely months before North American Free Trade Agreement (NAFTA). Procampo substituted previous price supports. It consists of an income transfer to landowners who grow or recently grew barley, beans, maize, cotton, rice, sorghum, soybean, safflower and wheat. Procampo's main goal is helping domestic producers of staples face competition from the United States and Canada, or turn into more competitive crops. It is scheduled to conclude in 2008, when free trade is achieved. Transfers to producers are decoupled: they are area-dependent and unlinked to productivity. The transfers are maintained after beneficiaries turn into alternative crops.

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

Restriction of government involvement in agriculture was accompanied by the disappearance of state-owned companies linked to this sector. Also *Conasupo*, fertilizer, seed and other companies supplying inputs to agriculture were either closed or privatized. Subsidized government credit was also reduced.

Another fundamental reform was that of Article 27 of the Mexican Constitution, promoted by the Salinas administration, in 1991, to grant property rights to the *ejidal* sector. The reform put an end to land distribution and the ban on the *ejidal*-land market. Promotion of the land market was meant to help capitalize agricultural activities by giving peasants access to the private-credit market and allowing private investment in agriculture.

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[19] To facilitate producers' transition from price supports to free markets, in 1994 a "de-coupled" income support programme for all farmers producing basic crops was complemented under the name of Procampo (Yúnez, 2003).

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

5.2 Trade Liberalization and NAFTA

Although Mexico became part of the General Agreement on Trade and Tariffs (GATT) in 1986, there were no major changes at that time in the protection given to the maize sector: import licenses remained in place until the implementation of North American Free Trade Agreement (NAFTA) in January 1994 and the Uruguay Round in 1995. NAFTA put an end to the barriers to Canadian and, especially, American maize exports (Dyer, 2003). Mexico signed two different agricultural agreements: one with Canada and the other with the United States. Agricultural trade liberalization also benefited members of GATT participating in the Uruguay Round.

Dyer and Yúnez (2003) argue that: "…Maize seed imports were completely liberalized at the start of NAFTA, but other maize (grain) was subject to a gradual liberalization scheme that will end in 2008. The scheme—tariff rate quota—consists of a tariff-free quota and a fixed tariff on above-quota imports. The initial quota was based on trade volumes between Mexico and its North American partners during the 1989–1991 periods. In 1994, the quota was set at 2.5 million metric tons for the United States and 1 thousand metric tons for Canada, and the above-quota tariff was set at 215 percent (or US$206.4/metric ton). Every year, the quota is raised and tariffs reduced until they are abolished in 2008. Until 1999, the full quota was allocated to Conasupo, the livestock-feed industry and private maize processors. The Secretariat of Agriculture and Conasupo would estimate the amount of maize imports required by the latter to accomplish its functions (grain storage and supply to *tortilla* producers under the subsidized-*tortilla* program). Up to 2000, the Mexican government did not collect the above-quota tariffs whenever the quota was exceeded".

5.3 The Environmental Policy in Mexico

In response to environmental deterioration and natural resources degradation in the last decades, the environmental policy has changed fro a basically sanitary direction, as a response to the air pollution in the biggest cities; the pollution of bodies of water and soils, towards a social involvement and ecological balance protection approach, these were the contributions of a higher social conscience and the importance conferred to the environmental problems solutions.

In the recent years, they were allocated higher although insufficient resources to the environmental sector and it was encouraged the institutional integration of polices and programs to agree the public management regarding environmental matters and the management and preservation of natural resources. It was changed the legal framework to specify the assignment of policymakers and responsibilities among the different governmental areas and to make possible the social involvement in the design and assessment of public policies on this matter.

The Secretariat of the Environmental, Natural Resources and Fisheries (Secretaria del Medio Ambiente, Recursos Naturales y Pesca –SEMARNAP), created on December, 1994, was the first of its kind in the history of the Federal Public Administration –Zedillo administration 1994-2000. The main purpose of SEMARNAP was to establish and increase the institutional structure of this sector and guide the future development of the country through sustainability <www.semarnat.gob.mx>.

The lack of importance that both government and society gave to this issue is evidenced with the small budget assigned to the environmental policy. The Mexican experience in environmental policy is not successful, for instance: the agricultural-livestock and agrarian policies have induced processes to deforestation and irrational use of soil. Programs such as Direct Support to the Countryside (Apoyos directos al campo –Procampo) or the one called Certification of Property Rights of Land Tenancy (Certificados de Derechos Ejidales y Titulación de Solares, PROCEDE) do not include the forest activity and in certain cases have resulted to be deforestation promoters.

After ten years of environmental management in Mexico, complete productive sectors continue deregulated or no considered by regulations and the environmental policy. These are the cases of agriculture, livestock, forest, fishery and services sectors. There is not a systematical coordination between sectors and policies makers.

5.4 Seed Improvement of Maize and Diffusion Programs in Mexico

The productivity of Mexico's maize-based cropping systems remains low by global standards, and many of the rural households that cultivate maize still live in poverty (between other factors). Meanwhile, aggregate demand for maize has steadily outpaced supply, leaving the country increasingly dependent on imports to close the widening consumption gap (Aquino, 1998). Once again, the small-scale producers are concentrated in the southern and central portions of the country, where rain-fed agriculture predominates. At other extreme, large-scale commercial producers grow maize primarily as a cash crop; most of these producers plant improved materials, especially hybrids. Large-scale producers are concentrated in the irrigated tracts of the central highlands and northern plains. Between these two extremes lie many intermediate types of producers.

Mexico is the second-largest maize-producing country in Latin America after Brazil. Annul production of maize in Mexico currently exceeds 18 million t. From 1961 to 1995, production grew at an average annual rate of 2.5% (Aquino, 1998). Harvested area changed little during this period, so the growth in production was entirely attributable to increased yields.

The Mexican government remains strongly committed to increasing the productivity of maize-based cropping systems and enhancing the wellbeing of rural populations. The government seeks to accomplish these objectives by increasing the effectiveness of maize research and technology delivery programs.

The Mexican maize seed industry is composed of public research institutes, the National Seed Production Agency (*Productora Nacional de Semillas* [PRONASE]) until 2004, national and transnational private seed companies, and rural producers' associations (Universities principally).

The public sector, Mexico's first publicly funded agricultural research station were established in 1906, whose mandate was to increase yields and production of basic crops, was formalized in 1932 with the creation of the Department of Experiment Stations (*Departamento de Campos Experimentales* [DCE]). In 1940, responsibility for the DCE was shifted to the newly created General Office of Experiment Stations (*Dirección General de Campos Experimentales* [DGCE]). In 1943, the Mexican government joined the Rockefeller

Foundation in establishing the Office of Special Studies (*Oficina de Estudios Especiales* [OEE]), which resulted in an immediate intensification of native germplasm collection and storage activities, as well as of plant breeding efforts (Aquino, 1998).

By 1947, when DGCE was transformed into the Institute of Agricultural Research (*Instituto de Investigaciones Agrícolas* [IIA]), agricultural research had advanced considerably. Research on maize, the nation's most important crop, was already producing results, as evidence by the release that year of the first improved Open Pollinated Varieties (OPVs). This development led to the creation of the Maize Commission, hose basic purpose was to organize the multiplication and distribution of improved maize seed in central Mexico.

In 1960, the IIA and the OEE were combined to create the National Institute of Agricultural Research (*Instituto Nacional de Investigaciones Agrícolas* [INIA]). This organization change, which was undertaken with technical and financial support from the United States government and private philanthropic foundations based in the U. S., was part of a board movement designed to strengthen national agricultural research systems throughout Latin America (Aquino, 1998). The Rockefeller Foundation, which had formerly played a leading role in maize research in Mexico through its participation in the OEE, was not assigned an official function under the new scheme. Instead, the foundation channeled its energies into creating a new organization, the International Maize and Wheat Improvement Center (*Centro Internacional de Mejoramiento de Maíz y Trigo* [CIMMYT[20]]). Following guidelines proposed by staff of the OEE and with financial assistance from the Mexican government, an institutional structure was developed to promote research on an international level.

In 1985, the INIA was reorganized into the National Institute of Forestry, Agriculture, and Livestock Research (*Instituto Nacional de Investigaciones Forestales y Agropecuarias* [INIFAP]). INIFAP was assigned responsibility for maize breeding efforts. Since law could distribute improved germplasm developed by INIFAP researchers only through PRONASE, private companies were effectively denied access to breeding materials and remained reluctant to undertake crop improvement research.

Seed industry reforms implemented beginning in 1991 provided greater access to INIFAP germplasm. The reforms eliminated the monopoly formerly held by PRONASE, clearing

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[20] See upper reference 18.

the way for increased private sector participation in maize breeding research. Seed companies responded by significantly increasing their investment in plant breeding, although the continued to relay heavily on INIFAP germplasm (Aquino, 1998).

INIFAP remains the preeminent public maize breeding organization in Mexico. Operating under a national mandate, research projects for maize are classified by production system, of which four currently receive priority attention: 1) highland systems, 2) mid-altitude systems, 3) tropical rain-fed systems, and 4) irrigated systems in northwestern Mexico. Judging from the number of materials produced, the INIFAP maize-breeding program has been very productive. Since 1966, approximately 170 OPVs and Hybrid have been released by INIFAP breeders, 10 of which were released during the period 1993-1995 (Aquino, 1998).

The INIFAP maize-breeding program benefits from CIMMYT germplasm. Because CIMMYT has a global mandate, its breeders do not disproportionately target Mexican production environments. Many of CIMMYT's breeding material (including tropical, subtropical, and highland materials) are selected and evaluated in Mexico, so they tend to be well adapted to Mexican conditions. Collaborative projects between INIFAP and CIMMYT help to ensure that this germplasm finds its way into INIFAP breeding plots.

Private Sector: for many years, private companies had little incentive to undertake maize breeding research in Mexico. Denied access to INIFAP germplasm, they could do little more than screen-imported materials. Although some hybrid imported from the southern United States performed passably in the irrigated districts of northern and central Mexico, imported materials generally could not compete with locally selected INIFAP materials in terms of adaptation.

This situation changed beginning in 1991 following the seed industry reforms, when a number of Mexican-registered seed companies launched modest maize breeding programs. Most of these programs used public germplasm obtained from INIFAP and CIMMYT as a starting point. In subsequent years, transnational companies jointed the original Mexican companies increasingly. Many of the inbred lines used to form hybrids were developed in Mexico; importing inbred lines was rarely attractive, because most imported lines were found to be poorly adapted to Mexican conditions (Aquino, 1998).

The marketing strategies adopted by private seed companies vary. Most companies distinguish among three of the market: 1) subsistence agriculture farmers who select their own seed, never invest in improved seed, and plant only local varieties; 2) marginal agriculture-farmers who occasionally purchase improved seed, with use of OPVs predominating; and 3) commercial agriculture-farmers who purchase improved seed annually, with use of hybrid seed being common. Demand for improved seed is concentrated in third segment, the one most often target by seed companies. Transnational companies concentrate exclusively on the commercial segment, because they specialize in the development and production of high-yielding hybrids suited to the needs of commercial farmers (Aquino, 1998).

One of the most efforts to diffuse seed throughout PRONASE was the price, because it does not have to recover any research costs through seed sales (Aquino, 1998). Costs incurred by INIFAP and other public breeding institutions are supported directly by the Mexican government. In contrast, private seed companies must recover their research costs through seed prices. Seeds from PRONASE are generally distributed in simple bag, which are market without extensive investment in advertising and promotional activities. An explicit objective of PRONASE is to provide seed for low-income farmers (Aquino, 1998). In contrast, private seed companies deliberately target commercial farmers who are willing and able to pay premium prices for high-quality seed.

5.4.1 Adoption of Improved Germplasm in Mexico

Aquino (1998) point out that during the period 1991-1995, the average area planted to maize in Mexico slightly exceeded 7.5 million ha, of which area about 80% was rain-fed and about 20% irrigated. Based on seed production data, it is estimated that approximately 1.6 million ha, or 21% of the total area under maize, were planted to improved OPVs and Hybrid[21]. The portion planted to improved seed was no stable throughout this period, however, rising from 16% in 1991 to 27% in 1993 before declining in 1994 and 1995.

Unlike earlier years, farmers who purchase improved seed currently favor hybrids. In 1995, nearly 90% of all improved maize seed sold in Mexico was hybrid seed, which was planted

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[21] Saín and Martínez (1999) argument that almost three-fourths of the farmer in rural Guatemala used local maize (Traditional Varieties) in 1991, while more than one-third used hybrids and improved varieties.

predominantly in irrigated zones but also in relatively favorable rain-fed zones where maize yields average 3 t/ha or more. Adoption of improved seed is most common among commercial farmers who cultivate large tracts of land using improved crop management practices and high levels of purchased inputs.

According to INIFAP, approximately 3 million ha in Mexico are located in irrigated zones and favorable rain-fed zones whose maize production potential is rated "very good" or "good". In hopes of speeding adoption, the government recently implemented a program of improved see exchange and distribution. Under the "Kilo por Kilo" program, government agencies deliver certified seed to farmers in exchange for an equal quantity of their current seed (usually seed of a Traditional Varieties or Landraces). The "Kilo por Kilo" program is aimed primarily at small-scale producers (defined as those who plant 20 ha or less) located in zones or high production potential. The goal of the program is to expand the area under improved seed to 3 million ha within 4 years.

6. Site Selection

The data, the survey and more information that is used and will be used in the PhD Thesis is part of one research project that was carried out by Dr. Mauricio Bellon and the Author between 2001-2003 at CIMMYT.

Site selection was based on a conceptual matrix that combined: (a) different levels of poverty and (b) levels of diffusion of MV, so as to have contrasting conditions on both axis (Figure 2). Since the focus of this *Tesina* is on MV, the first step was to delimit the areas where these varieties of maize are adapted. Delimiting this area for Oaxaca and Chiapas was accomplished through the use of a climatic and elevation model using data from collections of TV accessions at the CIMMYT genebank. Based on this information, was selected the coast of Oaxaca and the Frailesca region in Chiapas. Second, to identify different levels of poverty within the areas of adaptation, in the *Tesina* used the marginality index developed by the Consejo Nacional de Población (CONAPO) and the Programa de Educación Salud y Alimentación (PROGRESA) (CONAPO-PROGRESA 2000) as a proxy for poverty since direct data on poverty is not available. This index has been widely used by the Mexican government to target poverty reduction programs. This index does not measure poverty *per se*, but marginality—the lack of access to essential goods and services. Based on this index, localities throughout Mexico are classified into five levels of marginality: (1) very low; (2) low; (3) medium; (4) high; and (5) very high. It has the advantage of being available in a disaggregated fashion by locality and covers most of Mexico. Finally to identify areas with different levels of diffusion of MV, the data collection was carried out interviews with key informants and data on commercial seed sales and amount of seed distributed by government programs in the lowland tropical areas of Chiapas and Oaxaca. The information obtained from the government seed distribution program called "kilo por kilo". Information on this program was used as an indicator of diffusion of MV.

Figure 2: Matrix that depicts the design of the communities in the coast of Oaxaca, Frailesca, Chiapas, Mexico included in this study.

Marginality	Very High	High	Medium
Diffusion			
High	2	2	2
Low	2	2	2

Operationally and the purpose of this *Tesina* was decided to focus on the medium, high, and very high categories of the marginality index given as emphasis in poverty. In terms of diffusion, localities were classified as localities with low or high diffusion depending on whether they have been involved in the "kilo por kilo" program. Although this program is relatively recent (five years), according to local people, communities that benefited from it are the ones that have traditionally have been involved in government agricultural programs, which have been the main vehicle for access to improved seed.

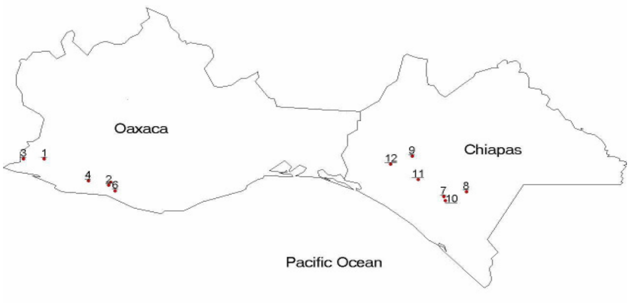
6.1 The Study Area

The 12 communities are: six in the coast of Oaxaca and six in the Frailesca, Chiapas. These communities correspond to two communities per cell in the conceptual matrix (one per region) (Figure 3). An additional criterion for selection was to include at least some communities with an important indigenous population. Community selection was not random but systematic, aimed at sampling the range of marginality levels, levels of improved germplasm diffusion and ethnicity.

The twelve communities that will be analyzing in the PhD Thesis are located in two highly contrasting regions: the coast of Oaxaca and the Frailesca, Chiapas (for simplicity these are referred to in the rest of the *Tesina* as Oaxaca and Chiapas, respectively). Communities in Chiapas have better access to government provided services and infrastructure even for a similar marginality level than those in the Oaxaca. Productive activities are more oriented to the market and the region has received strong support from state and national governments, particularly for agricultural development. This region produces important maize surpluses that are exported to other parts of Mexico, however still agriculture is dominated by small-scale farmers that produce both for the market and for their own consumption. There is an important diary industry and farmers can add value to their maize by using it as animal feed. The use of inputs and improved seed has been promoted through several government projects throughout the years.

In contrast, Oaxaca has been more isolated and has not received much government support for agricultural development. The state of Oaxaca imports substantial amounts of maize from other parts of Mexico and from outside. Although the coast of Oaxaca has better climate for maize and agricultural production than other regions of the state, it is not an important producer of this staple. Commercial agricultural activities are more biased towards extensive cattle ranching and maize production towards home consumption. Development has been more related to tourism, particularly in the southern part of the study area, where there are resorts such as Puerto Escondido, Puerto Angel, and Bahías de Huatulco.

Figure 3. Map of the communities included in this study



Communities	
Coast of Oaxaca:	**La Frailesca, Chiapa**
1. Santa Maria Cortijos	7. Libertad Melchor Ocampo
2. San Pedro Jicayan	8. Primero de Mayo
3. Santiago Jocotepec	9. Roblada Grande
4. Santa María MagdalenaTiltepec*	10. Dolores Jaltenango*
5. Santos Reyes Nopala*	11. Querétaro*
6. San Pedro Mixtepec	12. Rizo de Oro

7. Theoretical Concept of Adoption and Diffusion

The goal of this chapter is review empirical studies that have attempted to validate various aspects of adoption processes in the light of theoretical literature, considering all characteristics reviewed in the preceding chapters. The chapter examines different empirical works that analyzed technology adoption highlighting the findings and factors that affect the take-up of modern technology.

The role of Modern Varieties (MV) technologies in improving the well-being of agricultural households in developing countries has been widely documented and a large body of knowledge (adoption theory) emerged from this research on agricultural innovation, contributing that the farmers in developing areas face a multiplicity of constrains (e.g. lack of credit, infrastructure, or information) that prevent them from adopting MV. Theory suggested that some of this constrains (e.g. financial and information) would dissolve with the diffusion process itself, but the process could also be accelerated through investment in infrastructure, research, and extension. (Abdulai, 2005) point out that although research institutions engage in making scientific discoveries and in development of new technologies for farmers in poor countries, the adoption of innovations is frequently gradual and incomplete; sometimes technologies that would improve productivity are not adopted.

As a huge overview, it is possible to see the change in the form of population growth and technological innovation[22] occurs at different rates among communities, but it never ceases. Agricultural communities everywhere undergo the constant adjustment to new environmental conditions, environmental perturbations, technological innovations, contact with other groups, and demographic change. Agricultural evolution of Europe and North America is fairly well described, and innovation is accepted as a normal characteristic of these regions' farming systems. Unfortunately, historical data for agricultural evolution are less complete for other parts of the world, especially for regions where crop genetic resources are found; but there is no basis to suggest that a steady state existed there. The flux of genetic, human, biotic, and physical systems and their interaction make a steady state impossible to achieve or maintain (Brush, 1995).

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[22] Sunding *et. al.* (2001) define innovations as new methods, customs, or devices used to perform new tasks.

The Chapter tries to explain the adoption and diffusion theory briefly. The goal is to identify the differences between innovations and factors that influenced the acceptance. A distinction needs to be drawn, between new technologies that are divisible and innovation that are not divisible. The adoption in both levels: individual and aggregated farmers. Understand partial and whole adoption (Feder, 1985b). Furthermore, since the successful adoption and diffusion of new technology or innovation depend on both demand and supply forces, it is important to consider profitability from the point of view not only of the farmer but also of companies or enterprises (Heisey, 1998).

7.1 What is the Meaning of Adoption?

Numerous articles have been published on agricultural technology adoption in the last 30 years, ranking the "adoption issue" high on the economics research agenda Feder *et. al.* (1985b) survey paper on adoption, a milestone in the economics of adoption literature, cites more than 70 papers directly related to adoption studies in agriculture. Feder *et. al.* (1985b), define individual adoption i.e. adoption at the level of individual farm or firm, as the degree of use of new technology in the long run equilibrium when the farmer (or, in general, the rural entrepreneur) has full information about the new technology and its potential. The degree of use of a new technology may provide a quantitative measure of the extent of adoption when the new technology is divisible, i.e. when this can be divided to measurable units. For non-divisible innovations the extent of individual adoption is necessarily dichotomous (use-non-use or zero-one in quantitative terms).

"…Roger (1962), cited by Feder *et. al.*, defines the adoption process as the mental process an individual passes from the first hearing about innovation to final adoption". However for rigorous theoretical and empirical analysis, a precise quantitative definition of adoption[23] is need. Such a definition must distinguish between individual (farm-level) adoption and aggregation adoption. Final adoption at the level of individual farmer is defined as *the degree* of uses of a new technology in long-run equilibrium when the farmer has full information about the new technology and it is potential. The introduction of new technologies results in a period of disequilibrium behavior where resources are not utilized efficiently by the individual farm and learning and experimenting lead the farmer toward

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[23] The outcome of technology adoption is affected by dynamic processes that result in changes in prices of capital goods and input, learning by producers and users of capital goods, etc. Some of these processes have random components and significant uncertainty over time. Some of these dynamic considerations have been introduced to recent microlevel models of adoption behavior. Sunding *et. al.* (2001).

new equilibrium levels. Note, however, that, when the new technologies are constantly being modified, with some new innovations overlapping (recent technologies such as drip irrigation and automated water and fertilizer control can serve as extreme examples), the equilibrium levels may flow constantly and never be attained. In the context of aggregate adoption behavior, let the diffusion process be defined as "the process of spread of a new technology within a region". Aggregate adoption is measured by the aggregate level of use of a specific new technology within a given geographical area or a given population (Feder, 1985b).

In most cases, agricultural technologies are introduced in packages that include several components, for example, MV, fertilizer, and corresponding land preparation practices. While the components of a package may complement each other, some of them can be adopted independently. Thus farmers may face several distinct technologies options. They may adopt the complete package of innovations introduced in the region or subsets of the package. In these cases, several adoption and diffusion processes may occur simultaneously. However, such adoption processes may follow specific (and predictable) sequential patterns (Feder, 1985b).

The definition of adoption above refers to the degree of use of a new technology as a quantitative measure of the extent of adoption. A distinction needs to be drawn, however, between new technologies that are divisible (such as MV or new variable inputs) and innovation[24] that apply to the whole farm and are not divisible at a partial level (e.g. harvesters, tractors or machinery). The intensity of adoption for the farmer type of innovation can be measured at the individual farm level in a given time period by the amount or share of farm area utilizing the technology or by the per hectare quantity of input used where applicable. Analogous measure may apply at the aggregate level for a region. For non-divisible innovations, the extent of adoption at the farm level in a given period is necessarily dichotomous (use/no use); but, in the aggregate, the measure becomes continuous (e.g., the percentage of farmers using harvesters) (Feder, 1985b). Using these definitions of adoption and its quantitative measurement, the remainder of this sub-chapter posits a unifying framework for analyses of adoption patterns.

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[24] Sunding *et. al.* (2001) Categorize the agricultural innovation process between: mechanical innovation (tractors and combines), biological innovation (new seed varieties), chemical innovations (fertilizers and pesticides), agronomic innovations (new management innovations), biotechnological innovations, and informational innovations that rely mainly on computer technologies.

In most cases, adoption behavior differs across socioeconomic groups and over time. Some innovations have been well received, while other improvements have been adopted by only a very small group of farmers (Feder, 1985b). With respect to decisions of the farmer in a given period are assumed to be derived from the maximization of expected utility (or expected profit) subject to land availability, credit and other constrains. Profit is a function of the farmer's choices of crops and technology in each time period. It therefore depends on his discrete selection of a technology from a mix including the Traditional Variety technology and a set of components of the modern technology packages.

Most of the theoretical studies of the adoption behavior of individual farmers use static analysis that relates the degree of adoption to factors affecting it. These studies investigate the properties of the solution to particular cases of the temporal optimization problem of the farmer. One useful approach is to characterize the problem as one where the farmer has to choose between two technologies: the traditional technology, and the modern technology such as the use of MV and the inputs associated with them (fertilizer, irrigation and pesticides), with or without some form of fixed capital goods.

And most of the aggregate adoption models are dynamic and derive analytically the behavior of the diffusion process over the time. Much of these researches has been inspired by, and has attempted to explain, the frequent empirical findings of S-shaped patterns of aggregate diffusion over time.

7.2 Factors that Affect the Adoption

To summarized the vast amount of empirical literature on adoption systematically, Feder *et. al.* (1985b) organize the review of empirical work according to the key explanatory factors affecting adoption. There are a lot of related works in this way, which has a huge contribution in recent adoption knowledge: (Morris, M.L., R. Tripp, and A.A. Dankyi., 1999) where their findings coincide with (Sain, 1999) and (Kumar, 1994) works analyze the adoption and impact of improved maize varieties and recommend land management technologies on maize yield and factor payments. (Ransom, 2003) their analysis determined the socio-economic, physical and technological factors that influence the use of improved varieties by farmers. (Doss, 2003) analyzed 22 cases of study in Africa, in the same line, they review the factors that influence the adoption of new tech on maize, studying modern varieties. (Singh, 1997) in the same way, their work examined the use of improved maize seed in India. The study has multiple objectives: to quantify the current level of adoption of improved open-pollinated varieties and hybrids, to explore the relationship between adoption of improved germplasm and the use of improved crop management practices. (Wekesa, 2003) and a group work in the same line, studying the factors that influenced the adoption of new varieties of maize in the Coastal Lowlands of Kenya, Africa. (Smale, 1995) works analyze in terms of interrelated choices: one is whether to adopt only seed, only fertilizer, or both components of the technology.

Another choice relates to the extent of land allocation to modern and the farmers' seed varieties (extent of adoption). A third choice is the level per hectare of either seed or fertilizer or both (intensity of adoption), research that worthwhile pay attention, because not only study dichotomy adoption. Other interesting work is (Zepeda, 1997) where analyzed the role of wives in farm technology choice. Finally, a key work is (Brush, 1992) where analyze the loss of biological resources in agricultural systems due to the introduction of high-yielding varieties is a potential cost of agricultural development. Their findings provide empirical evidence that biological diversity on individual farms declines significantly as the area in improved varieties increases.

Most of the factors listed below, were statistical significant in these works:

7.2.1 Farm Size

Farm size can have different effects on the rate of adoption depending on the characteristics of the technology and institutional settings. More specifically, the relationship of farm size to adoption depends on such factors as fixed adoption cost, risk preferences, human capital, credit constraints, labor requirements, tenure agreements, and so on. Many empirical studies suggest that the use of MV and some variable inputs initially tends to lag behind on smaller farms.

7.2.2 Risk Considerations

The adoption of a new technology may expand the amount of risk with farming. Operators are uncertain about the properties and performance of a new technology, and these uncertainties interact with the random factors affecting agriculture. The number of risk associated with new technologies gives rise to several modeling approaches, each emphasizing aspects of the problem that are important for different types of innovations.

In particular, some models will be appropriate for divisible technologies and others for lumpy ones, and some will explicitly emphasize dynamic aspects while other will be static in nature.

Much of the agricultural adoption literature was developed to explain patterns of Modern Varieties (MV), many of which were introduced as part of the "Green Revolution". Empirical studies established that these technologies were no fully adopted by farmers in the sense that farmers allocated only part of their land to MV while continuing to allocate land to Traditional Varieties (TV).

7.2.3 Human Capital

By contrast with the subjective (learning) risk literature, the human capital empirical literature relating to adoption is well integrated with theory. The concept suggests that the contribution by the human capital factor to the returns from agricultural production can be attributed to worker ability and allocate ability. Formal schooling, however, is hypothesized to play a much more important role in determining allocate ability than worker ability. Several studies have investigated the effect of education, the results suggests that the farmers with better education are earlier adopters of modern technologies and apply modern inputs more efficiently throughout the adoption process.

7.2.4 Labor Availability

Labor availability is another often-mentioned variable affecting farmer's decisions about adoption of new agricultural practices or inputs. Some new technologies are relatively laborsaving, and others are labor using. For example, ox cultivation technology is laborsaving, and its adoption might be encouraged by labor shortage. On the other hand, MV technology generally requires more labor inputs, so labor shortages may prevent adoption. Moreover, new technologies may increase the seasonal demand of labor, so that adoption is less attractive for those with limited family labor or those operating in areas with less access to labor markets.

7.2.5 The Credit Constraint

Capital in the form of either accumulated savings or access to capital markets is required to finance many new agricultural technologies. Thus, differential access to capital is often cited as a factor in differential rates of adoption. This is the case with indivisible technology, in particular, such as tractors, or other machinery that requires a large initial investment. On the other hand, others have argued that lack of credit alone does not inhibit adoption of innovations that are scale neutral. Off-farm income can help to overcome a working capital constraint or may even finance the purchase of fixed-investment type of innovation. In fact, evidence suggests that rational farmers will evade the restrictions. In areas where adoption of divisible innovations (such as MV) depends on complementary indivisible investment (such as tube wells), lack of credit can impede the uptake of the divisible innovation by small farmer.

7.2.6 Tenure

Many empirical works suggests that any observed effect of tenancy may be indirectly due to the implied relationships between tenure and access to credit, input markets, product markets, and technical information. If these relationships vary in different sociocultural environments, empirical results may seem to conflict if the underlying factors are not consider directly. Thus, clear empirical results on the relationship between tenure and adoption may be lacking because many factors are yet to be considered appropriately. The conflicting empirical results regarding the relationship of the tenure and the adoption are in accordance with the unsettled debate in the theoretical literature over the relation between tenancy and adoption. The discussions point out the need to specify the terms of tenurial agreement explicitly for empirical work.

7.2.7 Supply Constraints

An important factor in explaining adoption patterns is the availability of complementary inputs. It is obvious that most farmers will not adopt MV seeds unless both seeds and some fertilizers are available; in most cases, the MV potential of the seed can be realized only if at least some fertilizers are applied. Thus, a sound study should determine whether behavior is supply constrained. But other inputs are also complementary to different degrees, for example, water and storage facilities (for perishable crops).

7.2.8 Trade Liberalization and Macroeconomic Policies

The adoption of innovation is likely to be significantly influenced by policies that affect the general economy. This may include trade and exchange rate policies as well as macroeconomic and credit policies. Macroeconomic policies that lead to high interest rates may reduce adoption because investment in new technologies is more costly. Adoption of mechanical innovations may suffer more significantly with high interest rates, while farmers may switch to technologies that are labor-intensive.

Changes in international trade regimens will affect various regions differently according to their relative advantage. The opening markets in the United States led to the introduction of high-value varieties in different communities in Central America. This change in cropping was combined with the establishment of a new infrastructure and the construction of packinghouses and the transportations facilities. Thus, when a change in trade rules seems permanent, it may lead to a complete overhaul of the infrastructure, and that may enable adoption of new crops and modernization (Sunding, 2001).

7.2.9 Environmental Policies

A wide array of environmental regulations affects technologies available for agriculture. Pesticides bans provide a strong incentive for the development of alternatives at the manufacturer level and for the adoption of alternatives strategies including nonchemical treatment, biological control, etc. On the other hand, the lack of availability of chemicals may retard adoption of MVs or new crops that are susceptible to a particular pest, specially in cases where nonchemical alternatives are not very effective (Sunding, 2001).

7.2.10 Input Subsidies

There is a wide body of literature that shows that subsidized water pricing tends to retard the adoption of modern irrigation technologies. However, subsidized input led to the adoption of MV and "green revolution" technologies in countries like India. They also increased profitability and thus have an indirect positive impact on adoption through credit effects. Similarly, subsidization of pesticides and fertilizers led to the adoption of MV and chemical intensive technologies in developing and develop countries alike, which is also likely to result in problems of environmental pollution since the environmental side effects of agriculture are often the result of excessive residues. Alternatively, elimination of subsidies and specially taxation of chemical inputs may lead to adoption of more precise application technologies that will reduce residues and actually may increase yield (Sunding, 2001).

7.2.11 Dynamic Considerations

The outcome of technology adoption is affected by dynamic processes that result in changes in prices of capital goods and input, learning by producers and users of capital goods, etc. Some of these processes have random components and significant uncertainty over time. Some of these dynamic considerations have been introduced to recent microlevel models of adoption behavior.

7.2.12 Price Supports

The mechanism through which price supports impact the adoption behavior of farms of different sizes varies. Smaller farms may increase their adoption because of price supports (their impact on credit) and the reduction in the minimum size required to justify adoption. Larger farms that may be risk diversifiers will increase the share of modern technologies on their land because of the mean effect and the reduction in risk. Price supports may also enhance adoption of mechanical innovations when they increase the relative profitability of operations with a new technology and thus reduce the size threshold required for adoption. Price support may enhance adoption also through their impact on credit. When the ability to obtain credit depends on expected incomes, price support will increase adoption when credit is constrained.

7.2.13 Output Taxation

Taxation of agricultural outputs, prevalent especially in developing countries, has a disastrous effect on technological change. It reduces the incentive to adopt MV, increases the price of agricultural land, thus reducing the ability to borrow. Furthermore, with lower prices, there are incentives to apply intensively modern inputs, which are associated in many cases with the adoption of Modern Varieties, in developing countries.

7.3 Diffusion Theory

As introduction, Perales *et. al.* (2005) arguments that diffusion from Human Ecologist view: "…define that culture as a mechanism that organizes the flow of information essential for survival. Cultures develop traditional knowledge based on experience and adoption to a local environment. Traditional knowledge is commonly well developed for genetic resources because of their paramount importance for survival of communities practicing subsistence agriculture. The transmission of this knowledge is biased by language and local cultural differences; an example of this bias is individuals confirming to local practices because doing so is less costly than experimenting and learning". One excellent example is that since maize was domesticated 5,000-10,000 years ago in Mesoamerica (Pandey, 1998), farmers have developed an enormous number of varieties that not only meet specialized consumption preferences but also show excellent adaptation to local growing conditions (Morris, 2002). The maize diffusion throughout the America continent was before 1400 AD and worldwide after 1500 AD (Brush, 2004). Between other crops, those have been diffused worldwide before of large body of marketing mechanism and innovations.

The work of Sunding and Zilberman (2001) on the adoption and diffusion theory argues that there is often a significant interval between the time that an innovation is developed and available in the market, and the time it is widely used by producers. Adoption and diffusion are the process governing the utilization of innovations.

Diffusion can be interpreted as aggregate adoption. Diffusion studies an innovation that penetrates its potential market. As adoption, there may be several indicators of diffusion of a specific technology. For example, one measure of diffusion may be the percentage of the farming population that adopts new innovations. Another is the land share in total land on which innovations can be utilized. These two indicators of diffusion may well convey a different picture (Sunding, 2001).

While it is helpful to use the term "adoption" in depicting individual behavior towards a new innovation and "diffusion" in depicting aggregate behavior, in cases of divisible technology, some economists tend to distinguish between intra-firm and inter-firm diffusion. For example, this distinction is especially useful in multi-plant or multi-field operations. Intra-firm studies may investigate the percentage of a farmer's land where drip irrigation is used, while inter-firm studies of diffusion will look at the percentage of land devoted to cotton that is irrigated with drip systems (Sunding, 2001).

Rural sociologists undertook studies of adoption and diffusion behaviors initially. The sociologists found that in most counties diffusion was an S-shaped function of time. Many of the studies of rural sociologists emphasized the importance of distance in adoption and diffusion behavior. They found that regions that were farther away from a focal point (e.g.

major cities in the state) had a lower diffusion rate in most time periods. Thus, there was emphasis on diffusion as a geographical phenomenon (Sunding, 2001).

7.3.1 The S-shaped Diffusion Curve

The work of Sunding and Zilberman (2001) comment that statistical studies of diffusion have estimated equations of the form:

$$Y_1 = K\left[1+e^{-(a+bt)}\right]^{-1}$$

where Y_1 is diffusion at time t (percentage of land for farmers adopting an innovation), K is the long-run upper limit of diffusion, a reflects diffusion at the start of the estimation period, and b is a measure of the pace of diffusion.

With an S-shaped diffusion curve, it is useful to recognize that there is an initial period with a relatively low adoption rate but with a high rate of change in adoption.

Figure 4: S-shaped diffusion curve

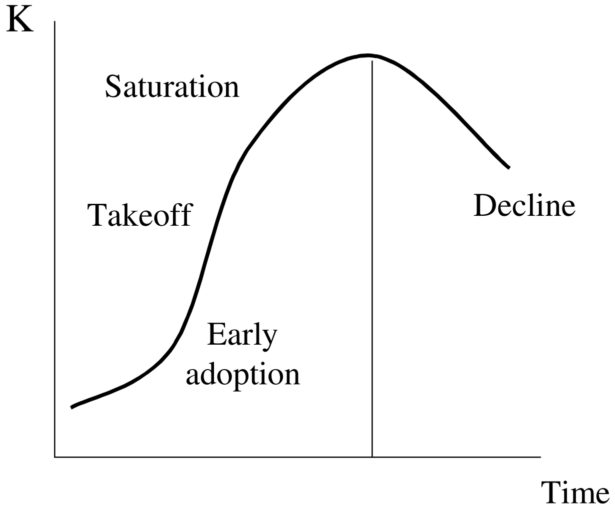


Figure 4 shows this as a period of introduction of a technology. Following is a takeoff period when the innovation penetrates the potential market to a large extent during a short period of time. During the initial and takeoff periods, the marginal rate of diffusion actually increases, and diffusion curve is a convex function of time. The takeoff period is followed by a period of saturation where diffusion rates are slow, marginal diffusion declines, and the diffusion reaches a peak. For most innovations, there will also be a period of decline where the innovation is replaced by a new one (Sunding, 2001). The S-shaped diffusion curves have been used widely in marketing to depict diffusion patterns of many products, for example, consumer durables. Diffusion studies have been an important component of the literature on economic development and have been used to quantitatively analyze the processes through which modern practices penetrate markets and replace traditional ones.

7.3.2 Diffusion as a Process of Imitation

Formal models used to depict the dynamics of epidemics have been applied by Mansfield (1963) cited by Sunding *et. al.*, derive the logistic diffusion formula. Mansfield viewed diffusion as a process of imitation wherein contacts with others led to the spread of technology. He consider the case of an industry with identical producers, and for this industry the equation of motion of diffusion is

$$\frac{\partial Y_t}{\partial_t} = bY_t\left(1 - \frac{Y_t}{K}\right) \quad (1)$$

Equation (1) states that the marginal diffusion a time $t(\partial Y / \partial t$, the actual adoption occurring at $t)$ is proportional to the product of diffusion level Y_t and the unutilized diffusion potential $(1 - Y_t / K)$ at time t. The proportional coefficient b depends on profitability, firm size, etc. Marginal diffusion is very small at the early stages when $Y_t \to 0$ and as diffusion reaches its limit, $Y_t \to K$. It has an inflection point when it switches from and early time period of decreasing marginal diffusion $(\partial^2 Y / \partial t^2 < 0)$. For innovation that will be fully adopted in the long run $(K = 1)$.

$$\frac{\partial Y_t}{\partial t} = bY_t(1 - Y_t)$$

the inflection point occurs when the innovation is adopted by 50 percent of producers. Lehvall and Wahlbin (1973) cited by Sungin *et. al.*, expanded the modeling of the technology diffusion process by incorporating various factors of learning and by separating firms that are internal learners (innovators) form those that are external learners (imitators) (Sunding, 2001).

7.3.3 Geographic Considerations

Much of the social science literature on innovation emphasizes the role of distance and geography in technology adoption. Producers in locations farther away from a regional center are likely to adopt technologies later. This pattern is consistent with the findings of threshold models because initial learning and the establishment of a new technology may entail significant travel and transport costs, and these costs increase with distance.

Diamond's (1999) book –cited by Sunding (2001)- on the evolution of human societies emphasizes the role of geography in the adoption on agricultural technologies. China and the Fertile Crescent have been source regions for some of the major crops and animals that have been domesticated by humans. Diamond argues that the use of domestic animals spread quickly throughout Asia and laid the foundation for the growth of the Euro-Asia civilizations that became dominant because most of these societies were at approximately the same geographic latitude, and there were many alternative routes that enabled movement of people across regions. The diffusion of crop and animal systems in Africa and the Americas was more problematic because population movement occurred along longitudinal routes (south to north) and thus, technologies required substantial adjustments to different climatic conditions in different latitudes. There were other geographic barriers to the diffusion of agricultural technologies. For example, the slow evolution of agricultural societies in Australia and Papua New Guinea is explained bye their distance from other societies, which prevent diffusion of practices form elsewhere.

Geography sets two barriers to adoption: climatic variability and distance. Investment in infrastructure to reduce transportation costs (e.g., roads and telephone lines) is likely to accelerate adoption. One reason for the faster rate of technological adoption in the United States is the emergence of a national media and the drastic reduction in the cost of access the resulted from the establishment of railroads, the interstate highway system, and rural electrification.

Distance is a major obstacle for adoption of technologies in developing countries. The impediment posed by distance is likely to decline with the spread of wireless communication technologies. It is greater challenge to adopt technologies across different latitudes and varying ecological conditions. The establishment of international research centers that develop production and crop systems for specific conditions is one way to overcome this problem.

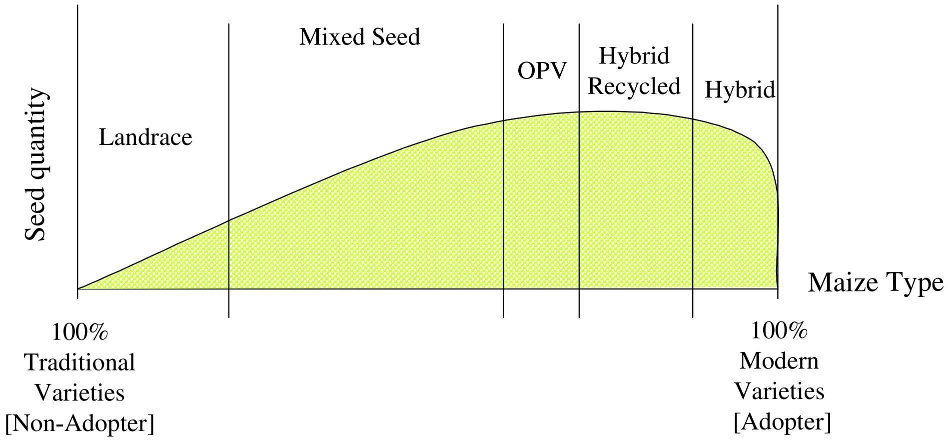
8. Econometric Model to Small-scale Mexican Farmers

This chapter develops the econometric model, which will be applying in the advanced research by the author. The preceding chapters examined the maize production importance and their uses between developing and industrialized countries, and the differences between Modern and Traditional Varieties of maize; then, a briefly analysis of socioeconomic small-scale farmer characteristics –income and activities diversification-; review the agricultural policy reform in Mexico as mandate of technological change; and the study of theoretical concept of adoption and diffusion –factors or polices that affect the adoption of innovation-. And review different works about adoption and the methods used in those works.

8.1 Seed Available to Farmers

Worthwhile remember the hypothesis: the non-adopter farmer conserve maize biodiversity *de-facto* in one side of the seed spectrum, without use of fertilizer and pesticides; the adopter may be cause erosion on maize biodiversity (mono-cropped) and pollution using fertilizer and pesticides (as oil-based product) situated in the other side of the spectrum (see figure 5). The questions are: How does small-farmer decide whether or not to plant a Modern Variety? What factors influenced their choice? What Agricultural Policy Reforms affect the choices of small-farmer decisions? What is the probability to switch from Traditional to Modern Varieties? Are there farmers that have both traditional and modern varieties, or mixed it? How do small farmers respond the paradox between conserve CGR and Improve Crop Yield?

Figure 5: Seed Spectrum



Bellon *et. al.* (2003) identified five categories of maize type: hybrids, recycled hybrid, open pollinated improved varieties, creolized varieties, and landraces. His classification was based on: (a) the name provided by the farmers, (b) whether the farmer said that the seed came from a "bag" –as new seed-, (c) the number of years seed was used, (d) information on its origin from the farmer and focus groups discussions, and (e) classification by a maize taxonomist of a collection of maize samples from the all the communities of study. The Figure 6 shows the criteria to classify the varieties. These categories will be using in the *Tesina* as Seed Spectrum.

Figure 6: The table shows criteria to classify varieties into five categories

Category	Criteria
Hybrid	• Name provided by farmer of a known hybrid • Seed came from a "bag" and first year of planting • Focus groups identified the name as being introduced to the community by government or commercial outlet • Maize taxonomist indicated that sample with same name was of a hybrid or recycled hybrid
Recycled Hybrid	• As above, but farmer had planted the seed from the previous harvest up to four years
Open Pollinated Variety	• As above, but name provided by the farmer was from a known OPV • Seed had been planted for first time or recycled up to four years
Creolized	• Any of the above, but farmer had recycled the seed for more than four and up to 15 years
Landrace	• Name provided by farmer of a known maize race (e.g. *Zapalote, Tepecente, Olotillo*) • It did not have a specific name (*maiz blanco*) but had been planted for many years either by farmer or somebody else in the community • It did not came from a bag • Focus group identified the name as a local variety • Maize taxonomist indicated that the sample with the same name was a landrace

Source: Bellon *et al.* (2003)

8.2 The econometric model

When the small farmer in Southern Mexico decide what seed to plant the next season he could choose among five alternatives: (1) Hybrid [H], (2) Recycled Hybrid [RH], (3) Open Pollinated Variety [OPV], (4) Creolized [C] and (5) Landrace [L] materials. It is possible to assume that a utility is associated with each alternative and the individual chooses that alternative for which the utility is greatest, as shown in the section *2. The Maize*, where productivity can be expressed in different ways, one commonly used measured is grain yield per unit land area. With good management, commercial maize grain yields often reach 10 tons per hectare (t/ha) or more in favorable production environments. In contrast, subsistence farmers in marginal areas frequently harvest 0.5 t/ha or less of grain from their maize plots.

Here is a single decision among five alternatives. There are two types of choices sets, *ordered* and *unordered*. The choice among means of getting to plant –by maize type: (1) H, (2) RH, (3) OPV, (4) C and (5) L- are clearly unordered. A bond rating is, by design, a ranking; that is it purpose. As we shall see, quite different techniques are used for the two types of models. Models for unordered choice sets are considered first, and second model for ordered choice is described below.

8.2.1 Model for Unordered Choice

Unordered-choice models can be motivated by a random utility model. For the i th consumer faced with J choices, suppose that the utility of choices j is

$$U_{ij} = \beta' z_{ij} + \varepsilon_{ij}$$

If the farmer makes choices j in particular, then we assume that U_{ij} is the maximum among the J utilities. Hence, the statistical model is driven by the probability that choice j is made, which is

$$Prob(U_{ij} > U_{ik}) \text{ for all other } k \neq j.$$

The model is made operational by a particular choice of distribution for the disturbances. Because of the need to evaluate multiple integrals of the normal distribution, the probit model has found rather limited use in this settings (Greene, 2000). The logit model, in contrast has been widely used in many fields, including economics, market research, transportation, and adoption. Let Y_i be a random variable that indicates the choice made.

Greene (2000) has shown that if (and only if) the J disturbances are independent and identically distributed with *Weibull* distribution,

$$F(\varepsilon_{ij}) = \exp(-e^{-\varepsilon_{ij}}),$$

then

$$Prob(Y_i = j) = \frac{e^{\beta' z_{ij}}}{\sum_{j=1}^{J} e^{\beta' z_{ij}}} \quad (8.1)$$

which leads to what is called the conditional logit model.

Utility depends on x_{ij}, which includes aspects specific to the individual as well as to the choices. It is useful to distinguish them. Let $z_{ij} = [x_{ij}, w_i]$. Then x_{ij} varies across the choices and possibly across the individuals as well. The components of x_{ij} are typically called the *attributes* of the choices. But w_i contains the characteristics of the individual and is, therefore, the same for all choices. If we incorporate this fact in the model, then (8.1) becomes

$$Prob(Y_i = j) = \frac{e^{\beta' x_{ij} + \alpha' w_i}}{\sum_{j=1}^{J} e^{\beta' x_{ij} + \alpha' w_i}} = \frac{e^{\beta' x_{ij}} e^{\alpha'_i w_i}}{\sum_{j=1}^{J} e^{\beta' x_{ij}} e^{\alpha'_i w_i}}$$

Terms that do not vary across alternatives –that is, those specific to the individual—fall out of the probability. Evidently, if the model is to allow individual specific effects, then it must be modified. One method is to create a set of dummy variable for the choice and multiply each of them bye the common w. We then allow the coefficient to vary across the choices instead of the characteristics. Analogously to the linear model, a complete set of interactions terms creates a singularity, so one of them must be dropped (Greene, 2000).

8.2.2 Multinomial logit model for maize choice

The purpose is to use a Multinomial Logit (ML) model to analyze the *Tesina* problem. In the ML the utilities for different alternatives *unordered* are independent. The data for each individual in the sample consist of the following:

1. [Dependent] Maize Type: (1) = H, (2) = RH, (3) = OPV, (4) = C, (5) = L.

2. [Independent] Factors: constant, education, size-plot, market-credit access, kilo-por-kilo program, poverty-characteristics, and off-farm activities, between others.

The model for Maize-Type choice is:

$$Prob(Y_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{k=0}^{5} e^{\beta_k' x_i}}, \; j = 0,1,\ldots,5. \; (8.2)$$

The model in (8.1) is a Multinomial Logit Model (Greene, 2000). The estimated equations provide a set of probabilities for the $J+1$ choices for a decision maker with characteristics x_i. Before proceeding, Greene (2000) suggest remove an indeterminacy in the model. If we define $\beta_j^* = \beta_j + q$ for any vector q, and then the identical set of probabilities result because the terms involving q all drop out. A convenient normalization that solves the problem is to assume that $\beta_0 = 0$ Therefore, the probabilities are:

$$Prob(Y = j) = \frac{e^{\beta_j' x_i}}{1 + \sum_{k=1}^{J} e^{\beta_k' x_i}}, \; j = 1,\ldots,J, \; (8.3)$$

$$J \; \ln\left[\frac{P_{ij}}{P_{ik}}\right] = x_j'(\beta_j - \beta_k). \; j \; Prob(Y = 0) = \frac{1}{1 + \sum_{k=1}^{J} e^{\beta_k' x_i}}.$$

The model implies that we can compute any other log-odds ratios

$$\ln\left[\frac{P_{ij}}{P_{i0}}\right] = \beta_j' x_i.$$

We could normalize on any other probability as well and obtain

Greene (2000) argues that estimation of the multinomial logit model is straightforward. Newton's method will normally find a solution very readily unless the data are badly conditioned. The log-likelihood can be derived by defining, for each individual, $d_{ij} = 1$ if alternative is chosen by individual i, and 0 is not, for the $J+1$ possible outcomes. Then, for each i, one and only one of the d_{ij}'s is 1. The log-likelihood is a generalization of that for the binomial probit or logit model:

$$\ln L = \sum_{i=1}^{n} \sum_{j=0}^{J} d_{ij} \ln Prob(Y_i = j).$$

The derivatives have the characteristically simple form

$$\frac{\partial \ln L}{\partial \beta_j} = \sum_i [d_{ij} - P_{ij}] x_i \ \text{ for } \ j = 1, \ldots, J.$$

The exact second derivatives matrix has $J^2 K \times K$ blocks,

$$\frac{\partial^2 \ln L}{\partial \beta_j \partial \beta_l'} = -\sum_{i=1}^{n} P_{ij} [1(j = l) - P_{il}] x_i x_i',$$

where $1(j = l)$ equals 1 if j equals l and 0 if not. Since the Hessian does not involve d_{ij}, these are the expected values, and Newton's method is equivalent to the method of scoring. The Berndt method can be used instead by summing the outer products of the first derivatives. This method will rarely be an improvement, however, because of the very simple form and global concavity of the log-likelihood. It is worth noting that the number of parameters in this model proliferate with the number of choices, which is unfortunate because the typical cross section sometimes involves a fairly large number of regressors.

The coefficients in this model are difficult to interpret. It is tempting to associate β_j with the j th outcome, but that would be misleading. By differentiating (8.3), we find that the marginal effects of the characteristics on the probabilities are

$$\delta_j = \frac{\partial P_j}{\partial x_i} = P_j [\beta_j - \sum_{k=0}^{J} P_k \beta_k] = P_j [\beta_j - \overline{\beta}]. \quad (8.4)$$

Therefore, every subvector of β enters every marginal effect, both through the probabilities and through the weighted average that appears in δ_j. These values can be computed from the parameter estimates. Although the usual focus is on the coefficient estimates, equation (7.4) suggests that there is at least some potential for confusion. For purposes of the computation, let $\beta = [0, \beta_1', \beta_2', \ldots, \beta_j']'$. We include the fixed 0 vector for outcome 0 because although $\beta_0 = 0, \gamma_0 = -P_0 \overline{\beta}$, which is not 0. Note as well that Asy. $Cov[\hat{\beta}_0, \hat{\beta}_j] = 0$ for $j = 0, \ldots, J$. Then

$$Asy.Var[\hat{\delta}_j] = \sum_{l=0}^{J} \sum_{m=0}^{J} \left(\frac{\partial \delta_j}{\partial \beta_l'} \right) Asy.Cov[\hat{\beta}_l, \hat{\beta}_m] \left(\frac{\partial \delta_j'}{\partial \beta_m} \right),$$

$$\frac{\partial \delta_j}{\partial \beta_j} = [1(j = l) - P_l][P_j \mathrm{I} + \delta_j x'] + P_j [\delta_l x'].$$

Finding adequate fit measure in this setting present the same difficulties as in binomial models. As before, it is useful to report the log-likelihood. If the model contains no covariates and no constant term, then the log-likelihood will be

$$\ln L_c = \sum_{j=0}^{J} n_j \ln\left(\frac{1}{J+1}\right)$$

If the regressor vector includes a constant term, then the restricted log-likelihood is

$$\ln L_0 = \sum_{j=0}^{J} n_j \ln\left(\frac{n_j}{n}\right) = \sum_{j=0}^{J} n_j \ln p_j,$$

where p_j is the sample proportion of observations that take choice j. If desired, the likelihood ratio index can also be reported.

Greene (2000) argue that a natural alternative model that relaxes the independence restrictions built into the multinomial logit model is the multinomial probit model. But, the main obstacle to implement the multinomial probit model has been the difficulty in computing the multivariate normal probabilities for any dimensionality higher than 2.

8.2.3 Model for ordered choice

Some multinomial-choice variables are inherently ordered. The multinomial logit or probit bodels would fail to account for the ordinal nature of the dependent variable. Ordinary regression analysis would err in the opposite direction, however. Take the outcome of an opinion survey. If the responses are coded 0, 1, 2, 3, or 4, then linear regression would treat the difference between a 4 and 3 the same as that between a 3 and a 2, whereas in fact the are only a ranking.

The ordered logit and probit models have come into fairly wide use as a framework for analyzing such responses. The model is built around a latent regression in the same manner as the binomial probit model:

$$y^* = \beta' x + \varepsilon$$

As usual, y^* is unobserved. What we do observe is

$$y = 0 \text{ if } y^* \le 0$$

$$y = 1 \text{ if } 0 < y^* \le \mu_1,$$

$$y = 2 \text{ if } \mu_1 < y^* \mu_2,$$

$$\vdots$$

$$y = J \text{ if } \mu_{J-1} \le y^*,$$

which is a form of censoring. The μ's are unknown parameters to be estimated with β. Consider, for example, an opinion survey. The respondents have their own intensity of feelings, which depends on certain measurable factors x and certain unobservable factors ε. In principle, they could respond to the questionnaire with their own y^* if asked to do so. Given only, say, five possible answers, they choose the cell that most closely represent their own feelings on the question.

Assuming that ε is normally distributed across observations. For the same reasons as in binomial probit model (which is the special case of $J = 1$), we normalize the mean and variance of ε to 0 and 1. (The model can also be estimated with a logistically distributed disturbance. This trivial modification of the formulation appears to make virtually no difference in practice.) With the normal distribution, we have the following probabilities:

$$\begin{aligned} Prob(y=0) &= \Phi(-\beta' x), \\ Prob(y=1) &= \Phi(\mu_1 - \beta' x) - \Phi(-\beta' x), \\ Prob(y=2) &= \Phi(\mu_2 - \beta' x) - \Phi(\mu_1 - \beta' x), \\ &\vdots \\ Prob(y=J) &= 1 - \Phi(\mu_{J-1} - \beta' x). \end{aligned}$$

For all the probabilities to be positive, we must have

$$0 < \mu_1 < \mu_2 < \cdots < \mu_{J-1}$$

The log-likelihood function and its derivatives can be readily, and optimization can be done by the usual means (see more at Greene [2000]). As usual, the marginal effects of the regressors x on the probabilities are not equal to the coefficients.

Most of the research works reviewed in the Chapter 7 used dichotomy variables as well Traditional and Modern Varieties. Here, using the seed-spectrum as multi-choice, the model could contribute to identify the probabilities to-switch from Traditional to Modern Varieties, taking into account independent variables as Agricultural-Policy Programs, Government-Programs, and access to MVs.

Finally, the further research, as PhD Thesis there is a correction to evaluate the extension of Adoption, it will be possible using Heckman* Extension (1979) two-steps procedure.

*Heckman J.J. 1979. Sample selection bias as a specification error. Econometrica 47:153-61.

9. Conclusions

As shown in proceedings chapters, by one side: today Maize is substantial part of human-food of millions of people around the third world. FAO's (2004a) report most of the world's 842 million hungry people live in marginal lands and depend upon agriculture for their livelihoods. Food-insecure households in these higher-risk rural areas face frequent droughts; degrade lands, remoteness from markets and poor markets institutions. For many of these people, food security will only come through increased agricultural production and income (FAO, 2004a). Biotechnology will play an important role in developing new germplasm with greater tolerance to abiotic and biotic stress and which higher nutritional content. In the other side: the agricultural production has an intense relationship with the environment, for a significant portion of land use and water consumption in some of the fields of farmers. Consequently, agricultural policies may have important environment impacts-both positive and negative-. Generally speaking, agriculture subsidies and technological adoption are thought to provide incentives for intensification of agricultural production. They do so by increasing farmers' revenues and providing incentives to increase output through more intensive use of inputs, such fertilizers and pesticides. Intensification of agricultural production can generate environmental impacts such as water pollution, land degradation, and biodiversity loss. Highlight those as a "paradox" of conservation Crop Genetic Resources and the necessity of million of hungry people.

A vast amount of economic literature on innovation and technology adoption in agriculture ends up by estimating a dichotomous adoption decision in terms of adoption or non-adoption. The *Tesina's* proposal is to use the Seed-Spectrum as assessment of how small-farmer responds of Agricultural and Environmental Policy, applying the econometric Multinomial-Logit (order and unordered data) is possible to understand the probabilities to switch from Traditional to Modern Varieties. Traditional Varieties are rich in genetic resources, maybe the farmer grown it without fertilizer, herbicide and pesticides –probably fewer rates than MVs-; in the other side, Modern Varieties respond to high inputs.

Analyzing the farmers' selection, adoption and the probabilities to change their technology or seeds we can understand how respond to this contradiction. Abdulai *et al.* (2005) argue that farmers decision to (or not to) adopt a new technology depends on the net benefits from adoption. But, is important understand how farmers respond to agricultural policy – subsidizing seed, fertilizer, pesticides, electricity tariffs and fuel oil-based-.

Respect to innovation and technology of maize, the sad reality is that significant numbers of small-scale, subsistence-oriented farmers have been ignored because they do not represent attractive customers for profit-oriented firms. Market-based solutions dearly do not work for these farmers who lack the resources needed to pay for the improved seed and the information needed to manage it properly. But, the good news is that these farmers keep a spectrum of traditional varieties and conserve maize biodiversity. Because private seed companies will tend to neglect small-scale farmers in marginal production environments who, because of their dispersed distribution, special germplasm requirements, and modest purchasing power, do not represent an attractive market (Morris, 1998c).

During last decade, and simultaneous growth of public and scholarly interest in crop conservation has shifted from *ex-situ* (gene bank) conservation to the *in-situ* (on-farm) approach (Brush, 1999). Brush (1995) argument that "…Factors that promote *in-situ* conservation are the fragmentation of land holdings, marginal agricultural conditions associated with hill lands and heterogeneous soils, economic isolation, and cultural values and preference for diversity. Maize Landraces are likely to persist in patches and islands of farming systems in regions of crop domestication[25] and diversity, and these patches provide potential sites for conservation crop genetic resources (CGR).

Market imperfections are endemic in rural areas of less developing countries. Missing or incomplete markets result from high transaction cost in factor or output markets (van Dusen, 2005). Risk or uncertainty, in the absence of a perfect insurance market, may also cause the household to plant a portfolio of varieties instead of specializing (van Dusen op cit.)

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[25] Domestication is a selection process conducted by humans to adapt plants and animals to the needs of humans, whether as farmers or consumers. Interestingly, this process of domestication has been conducted for some 10 000 yr, following the last Ice age, in several regions independently. Many traits selected under domestication, because they fit the needs or fancy of humans, are actually deleterious in the wild. A as consequence, fully domesticate crops may not survive in the wild without human intervention in planting and harvesting (Gepts, 2002).

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