Impact of Improved Maize Germplasm on Poverty Alleviation:

The Case of Tuxpeño-Derived Materials in Mexico

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CIMMYT® (www.cimmyt.org) is an internationally funded, not-for-profit organization that conducts research and training related to maize and wheat throughout the developing world. Drawing on strong science and effective partnerships, CIMMYT works to create, share, and use knowledge and technology to increase food security, improve the productivity and profitability of farming systems, and sustain natural resources. Financial support for CIMMYT's work comes from many sources, including the members of the Consultative Group on International Agricultural Research (CGIAR) (www.cgiar.org), national governments, foundations, development banks, and other public and private agencies.

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Abstract: This study documents the use of improved maize germplasm by poor small-scale farmers in lowland tropical Mexico and how it contributes to their well-being. To this end, the direct adoption of improved varieties and their "creolization" process were assessed. Farmers produce what they recognize as "creolized" varieties by exposing improved varieties to their conditions and management, continually selecting seed of these varieties for replanting and, in some cases, promoting their hybridization with landraces, either by design or by accident. Our key hypothesis is that improved germplasm benefits poor farmers through creolization, which provides them with new options. In creolization, farmers take an improved technology generated by the formal research system and deliberately modify it to suit their needs. Different methodologies such as participatory methods, ethnographic case studies, household surveys, collection of maize samples, and agronomic evaluation of those samples were applied in this study, which was conducted in two areas: the coast of Oaxaca and La Frailesca, in the states of Oaxaca and Chiapas, two of the poorest in Mexico. The study areas are contrasting—one subsistence-oriented and the other commercial—but extreme poverty is pervasive in both. Maize continues to play a key role in the livelihoods of the poor in both areas. Results show that different maize germplasm types, such as improved varieties and, particularly, creolized varieties, are planted in both areas. The impacts of different types of improved maize germplasm are defined and analyzed based on how well they supply farmers with traits they consider important, and the trade-offs they entail. Results also show that creolized varieties occupy a niche that shifts according to the availability of improved germplasm and the orientation of farmers' maize production.

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Preface

This monograph documents the results of a collaborative effort by a multidisciplinary group of scientists, aimed at gaining new insight into how poor small-scale farmers benefit from improved maize germplasm. The study originated in a concept that farmers themselves often expressed during fieldwork previously conducted by one of the authors. The scientists' main contributions were to take farmers' ideas and perceptions, translate them into testable hypotheses, and set up a framework within which to test them. Implications derived from the results go into areas which, although currently of no direct interest to local farmers, could eventually impact their lives greatly. The implications of this research may, for example, lead to new methods of developing and delivering maize germplasm that is more relevant to poor farmers and their livelihood strategies.

This study should be of particular interest to an institution such as CIMMYT, which is dedicated to alleviating poverty in the developing world partly by generating improved germplasm that responds to the needs of poor farmers. The results of this study will contribute to understanding the new dimensions by which farmers, particularly poor ones, benefit from improved maize germplasm within a livelihoods framework, both of which are core components of CIMMYT's new strategy and explicit components of the research reported here.

An important feature of this research is that it brought together a multidisciplinary team of scientists who applied different approaches to study how farmers benefit from improved germplasm. The different disciplines and approaches complemented and reinforced each other to reveal how local knowledge and practices interact with new, scientifically-bred varieties to create novel materials that respond to the unique needs of poor farmers and their families.

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This project was led by CIMMYT with IFPRI as a research collaborator. It is part of a six-country, seven-project study of the Impact of Agricultural Research on Poverty, managed by IFPRI under the auspices of the Standing Panel on Impact Assessment (SPIA) of the CGIAR.

Chapter 1

Introduction

Improved maize varieties have been available in Mexico for more than 40 years, but adoption of these varieties has been limited. Despite repeated government campaigns to encourage use of improved seed, today only about one-fourth of the total maize area in the country is planted to improved varieties. Most of this area is located in the commercial production zones of central and northwestern Mexico (Morris and Lopez-Pereira 1999). The relatively low adoption rate may give a misleading impression of the true impact of improved germplasm on the welfare of rural households. A growing body of evidence suggests that many small-scale, subsistence-oriented farmers have taken up improved varieties and planted them alongside local varieties. Farmers produce what they recognize as "creolized" varieties (*variedades acriolladas*)[1] through exposing improved varieties to their conditions and management, continually selecting seed of these varieties for replanting and, in some cases, promoting their hybridization with landraces, either by design or by accident (Bellon and Risopoulos 2001).

Conventional studies on the impact of germplasm usually focus on the area planted to improved varieties. To date, few attempts have been made to document the use of creolized varieties. The lack of studies on creolization constitutes a major gap, for if it is ignored, the benefits generated by formal plant breeding programs may be significantly underestimated. This study attempts to document how farmers in lowland tropical Mexico use improved maize germplasm both directly (by adopting improved varieties) and indirectly (by creating creolized varieties). It also attempts to determine how the use of improved germplasm contributes to the well-being of poor small-scale farmers.

Our key hypothesis is that poor farmers benefit from improved germplasm through creolization. While improved varieties provide desirable traits not found in landraces, they nonetheless may lack traits that landraces do provide (e.g., a distinguishing feature of landraces is their local adaptation); hence farmers choosing between them face trade-offs in the traits they seek. Creolization lessens these trade-offs by adapting improved varieties to farmers' conditions. Creolized varieties provide traits (or a combination of traits) not supplied by landraces and entail fewer trade-offs than improved varieties. Through creolization, farmers deliberately modify an improved technology generated by the formal research system to suit their own circumstances and needs.

1 Wood and Lenné (1997) use the term "rustication" for the process through which materials produced by formal plant breeding programs change in the hands of farmers.

This study involved three separate but related activities: (1) measuring and explaining adoption, local adaptation, and use of improved maize germplasm; (2) understanding how adoption choices are linked to the vulnerability and livelihood strategies of rural households; and (3) assessing the impacts of adoption on the welfare of rural households. The specific focus of the study was the Tuxpeño maize germplasm complex. One of approximately 250 maize landraces found in the New World, Tuxpeño was subjected to intensive breeding efforts, first, by a joint Rockefeller Foundation / Mexican Ministry of Agriculture program and, later, by their successors, the International Maize and Wheat Improvement Center (CIMMYT) and Mexico's National Institute of Forestry, Agricultural, and Livestock Research (Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias, INIFAP). Tuxpeño germplasm has been used by these and other institutions, including private companies, to breed both hybrids and improved open-pollinated varieties (OPVs).[2] This study was carried out in two regions: the coast of Oaxaca and La Frailesca, in Chiapas. Oaxaca and Chiapas are two of the poorest states in Mexico.

This study could contribute to a re-assessment of the impact of CIMMYT germplasm by incorporating a portion that has remained invisible up to now. It may also help CIMMYT to reflect on how to contribute more effectively to a farmer-led process that helps deliver innovations that are more appropriate to the needs and livelihood strategies of the poor. Further, this study should contribute to the debate on the role of centralized versus decentralized research or site versus non-site research, and the ability of these research modes to reach the poor.

The remainder of this paper is divided into six chapters. Chapter 2 describes the methods that were used in the study, particularly to design and conduct it. Chapter 3 presents a description of the two study areas. Though different in terms of development, degree of commercialization, and maize production, the study areas are similar in that in both poverty is widespread, and in both maize plays a key role in people's lives, despite their diversified livelihoods. The fourth chapter defines the different maize germplasm types studied and presents a history of their dissemination, including the origin of the seed used and its management. It shows that farmers plant many different types of maize germplasm, whose origins and management histories affect their choices. The fifth chapter presents the results of the adoption of different germplasm types. It describes how adaptation, management intensity, cultural factors, risk, and integration into regional and national economies all play a key role in the adoption process, which is nonetheless different for each germplasm type. Chapter 6 details the impacts of different germplasm types on farmers' well-being. Impacts are defined and

2 There are two types of improved maize varieties: hybrids and open-pollinated varieties (OPVs). Simply put, a hybrid is the result of crossing two inbred lines, while improved OPVs are populations that have been subjected to selection by breeders. If seed from a hybrid is replanted, it will not be as productive as the original seed and thus has to be purchased every season to maintain its high productivity. In contrast, seed from an OPV can be replanted usually up to three years without major drops in yield and, hence, can be purchased once every three years.

analyzed based on the extent to which each germplasm type supplies farmers with traits they consider important, and the trade-offs each entails. Men and women farmers in both study areas value multiple traits, which different maize types provide to different degrees; this implies there are trade-offs that farmers accept when they choose among these maize types. There is no "perfect" maize type; nevertheless, as hypothesized, creolized varieties represent a compromise between improved varieties and landraces for certain traits. Finally, Chapter 7 lists the conclusions of the study and what they imply for future research, whether conducted by international research centers or national agricultural research institutions.

Chapter 2

Methods

Diverse methodologies such as participatory methods, ethnographic case studies, a household sample survey, and the collection and agronomic evaluation of maize samples were used in this research. The overall design of this research was patterned after the sustainable livelihoods framework, the common conceptual framework for four other studies of the impact of agricultural research on poverty (Adato and Meinzen-Dick 2002).

Site Selection

Site selection was based on a conceptual matrix that combines poverty levels with levels of adoption of Tuxpeño-improved germplasm, so as to have contrasting conditions on the two axes (Figure 1). Since the focus of this research is Tuxpeño-derived germplasm, the first step was to delimit the areas where this germplasm is adapted. A climatic and elevation model based on data from Tuxpeño landrace collections in the CIMMYT genebank was used to delimit these areas in Oaxaca and Chiapas. Based on this information, we selected the coast of Oaxaca and the La Frailesca region in Chiapas. In identifying poverty levels within the areas of adaptation, we used the marginality index developed by Mexico's National Population Board (Consejo Nacional de Población, CONAPO) and the Education, Health, and Food Program (Programa de Educación, Salud y Alimentación, PROGRESA) (CONAPO-PROGRESA 2000) as a proxy for poverty, since direct data on poverty are not available.

Although widely used by the Mexican government to target poverty reduction programs, this index does not measure poverty *per se*, but marginality—i.e., the lack of access to essential goods and services. According to this index, locations in Mexico may be classified into five marginality levels: very low, low, intermediate, high, and very high. The index has the advantage of being available in disaggregated form, by location, and of covering most of Mexico. Finally, to identify areas with different levels of adoption of Tuxpeño-derived germplasm, we interviewed key informants and gathered data on commercial seed sales and the amount of seed distributed by government programs in the lowland tropical areas of Chiapas and Oaxaca. In particular, we obtained data on a government seed distribution program called Kilo por Kilo[3] and used them as an indicator of the dissemination of improved germplasm.

Marginality =>	Very high	High	Intermediate
Diffusion ⇓			
High	2	2	2
Low	2	2	2

Figure 1. Matrix depicting the design of the communities on the coast of Oaxaca, and in La Frailesca, Chiapas, Mexico, included in this study.

All this information was synthesized into a geographic information system (GIS) developed by the CIMMYT GIS, which was used to define potential locations for project fieldwork.

Given our emphasis on poverty, we decided to focus on the intermediate, high, and very high categories of the marginality index. We classified locations as low- or high-adoption sites, depending on whether they had been involved in the Kilo por Kilo program. According to local people, the program benefited communities that had traditionally participated in government programs, the main suppliers of improved seed. In view of the high number of locations, we decided to limit our potential sites to those having 1,000 to 2,500 inhabitants. The upper limit of 2,500 inhabitants is the parameter used in Mexico to define rural populations. The lower bound was chosen to capture a sufficient amount of intra-location variability in socioeconomic conditions.

We selected 12 communities, 6 on the coast of Oaxaca and 6 in La Frailesca, Chiapas, which in the conceptual matrix correspond to two communities per cell (one per region). An additional criterion for selection was to include several communities with a considerable indigenous population. Community selection was not random, but systematic, aimed at sampling the range of marginality levels, levels of improved germplasm dissemination, and ethnicity. We believe the selected communities are representative of the range of conditions in the two study areas. It should be stressed, however, that we adopted a case study approach to our research; the results presented in this report should thus be considered valid only for the 12 communities studied.

Focus Groups

Two types of focus groups were formed: "livelihood focus groups" and "technical focus groups." Livelihood focus groups centered on documenting farmers' livelihood strategies and their relationships with poverty, vulnerability factors, and local indicators of poverty and well-being. They were held in eight of the twelve study communities (four per state), selected to represent intermediate, high, and very high marginality levels. Technical focus groups were organized in all 12 study communities and concentrated mainly on technical issues related to farmers' perceptions of maize traits and how they respond to their needs, priorities, livelihood strategies, and vulnerability context. The following issues were discussed in each session: a) local taxonomy of maize varieties, their characteristics and history; b) varieties that have been abandoned and reasons for their loss; c) seed management practices; d) local knowledge of maize reproduction and improvement; e) local soil taxonomy; f) wealth ranking; g) inventory of productive activities in the community; and h) relationships between maize varieties and soil type and wealth ranking. Due to space constraints, in this document we report only the results of key topics.

In both focus groups there were separate sub-groups for men and women, to put them at their ease and facilitate participation. We unsuccessfully attempted to do the same based on wealth / poverty status. In the

[3] Part of a larger government program in support of agriculture called Alianza para el Campo, this program provided subsidized seed of improved varieties–mainly hybrids–to small-scale farmers. Initially, the program allowed farmers to exchange local seed for the same amount of improved seed; hence, its name. Later the program changed to provide farmers with seed of improved varieties at the price of local seed. The program was discontinued in 2001, but was in place when this research took place.

livelihood focus groups, we explained to community leaders responsible for recruiting group participants the need for forming separate wealth / poverty sub-groups. Many promised to do so, but in fact only sub-groups for men and women were convened. The research team perceived that the request struck villagers as potentially divisive, for it would have drawn lines between community members and emphasized their social differences. They also found our reasons for wanting to know who was richer / poorer suspect. In addition, when we asked about size of landholdings as a criterion to differentiate among them, this seemed to heighten concern that the information might be used against them.[4] This confirms that it is far easier to convene groups by socio-economic criteria when existing data gathered through a previous survey can be used to classify households. Although differentiation based on some form of local wealth ranking or self-assessment is used in participatory appraisals in Latin America (including Mexico), it appears to require a greater level of trust between group conveners and local communities. An alternative strategy is for researchers to get to know the community well enough to make these distinctions independently, as was done for the case studies (see below). In this study, as an alternative for disaggregated sub-groups, we asked each group to discuss differences between livelihood strategies and vulnerability for the better-off, average, and poorest farmers.

Participants in the technical focus groups were selected to gain the perspective of a range of farmers facing different conditions. This included old and young farmers, farmers with a reputation for knowing the maize diversity present in the community, farmers with limited access to information, and farmers living in marginal conditions. It should be pointed out that at the end of the discussions, we gave farmers a talk on maize reproduction and strategies to improve their maize varieties as a way to thank them for their participation. They seemed highly appreciative and commented that these issues had never been explained to them, and that many things they had observed in the field were now starting to make sense.

Household Case Studies

Forty household-level case studies were conducted in four villages (two villages per state), representing very high and intermediate marginality in Oaxaca, and very high and high marginality in Chiapas.[5] Two researchers carried out the studies, one in each state. Each researcher lived in two different communities over a period of three-and-a-half months. He / she lived with local families and participated in their daily lives in the house, fields, markets, and other public spaces. Every two weeks, the researcher would go to the other community he / she was studying. In each locale, the researcher carried out 10 case studies on households of different social strata, selected to roughly represent “extreme-poor,” “average-poor,” and “less-poor” farmers.

4 See page 20 for a description of people’s experience with PROCAMPO and their suspicions that the government wanted to take their land. A survey conducted for targeting PROGRESA also ran into problems when people were asked about landholdings (Adato et al. 2000). There were rumors that the government would take away people’s land based on perceptions of past government programs.

5 Although the research design called for achieving a degree of contrast as great as in Oaxaca, in Chiapas intermediate-marginality communities were too far from high-marginality communities, and travel between them exceedingly difficult. Because the difference in contrast is not great, and because we were more interested in differences among farmers than among communities, this was not considered a problem.

The researchers made this decision after they had gotten to know the villages and the people. They based their classification on their own perceptions as well as the villagers' views, collected for this purpose.

The case studies gathered complex data on daily life; economic and social activities; livelihood strategies and the role of maize; vulnerability and local understanding of poverty; local definition of maize varieties; maize management practices; social networks for seed distribution and maize marketing; attitudes toward government-supplied seed; and other areas. The methodology used to gather data were farmer observation and in-depth interviews that were recorded and later transcribed. Data were analyzed using HyperResearch software.

Household Survey

A survey of a representative sample of 325 farm households covering all 12 communities was conducted between October and December 2001. The survey questionnaire was partly developed using qualitative information generated within the focus groups. The survey elicited information on household characteristics such as family size and composition, on- and off-farm labor allocation, maize varieties and other crops planted, number and kinds of animals owned, maize consumption and marketing, and an inventory of household landholdings including detailed field characteristics. Sub-samples of plots were randomly selected from landholding data, and information was gathered on their specific management. In each community, a random sample of 27[6] households was drawn from all households engaged in farming and maize planting. Since the sample size was equal across communities but the number of farming households varied, the sampling fraction varied by community. Sampling weights (expansion factors) were used to correct for unequal representation. Expansion factors were applied to most calculations reported here.[7]

Farmers' evaluation of maize varieties

The survey included a section on farmers' evaluation of maize varieties, which covered 19 crop traits identified as significant in focus group discussions. The evaluation consisted of two parts: (1) an assessment of the importance to farmers of the identified traits, in which male and female farmers rated each trait as very important, important, or not important, in terms of its relevance for choosing a maize variety; and (2) an assessment of farmers' perceptions of the performance of each variety they grew relative to each previously identified trait. In each household, male and female farmers rated each variety separately as very good, good, poor, or very poor. Since women usually do not work in the fields, they were asked whether they actually participated in planting the variety or not. There were also instances in which currently grown varieties were not rated because the farmer did not feel that he/she knew enough about their performance. Later we grouped ratings of varieties by maize types according to definitions presented in Chapter 5.

[6] In one community 28 households were interviewed.

[7] Expansion factors were applied only within communities. Each community was not weighted according to its probability of selection—i.e., the data presented here assume an equal probability of selection for each community. That is why we claim that our results are valid for the 12 communities studied only.

The ratings of the importance of each trait for men and women in each study area were compared. Since men and women were not selected independently of each other, but were members of the same household (they were related), the non-parametric Wilcoxon signed ranks test was used to determine statistically significant differences between male and female ratings for each trait. To test whether the importance of a trait is related to poverty, we ran a non-parametric correlation between the importance rating of a trait and the expenditure of the household.

We used a proportional odds model (Agresti, 1996; Coe, 2002) to systematically examine farmers' perceptions of the varieties' performance with respect to traits they considered important. The model relates a dependent variable consisting of ordered response categories (e.g., farmers' ratings of performance for a trait) to a set of independent variables (e.g., types of maize germplasm grown by farmers and other covariates explained below) (see Appendix 1 for a brief explanation of the model). The model, estimated using PROC GENMOD in SAS (SAS, 2001), was run independently for each of the 19 identified traits, separately for men and women, and individually for the two study areas. The estimated coefficients reported in the chapter on impacts refer to the ratio between the odds that one germplasm type (e.g., hybrids) is rated higher for a trait (e.g., yield by weight) to the same odds for a different germplasm type (e.g., landraces). An example of the interpretation is presented in that chapter.

Due to the importance of taking poverty into consideration in the estimated models, we included the predicted expenditure of the household as a covariate to correct for differences in ratings associated with different welfare levels. The predicted expenditure was used because expenditure is endogenous. The predicted values for expenditure were derived from a regression of the log of expenditure against a set of explanatory variables associated with local perceptions of poverty and other measures of marginality. One regression was estimated for each study area (see Appendix 2). Because women may not have participated directly in growing many varieties and, hence, may have very limited knowledge and experience of the variety, which could bias their ratings, a dummy variable specifying if they actually had participated in growing the variety or not was included in the regressions of female ratings.

Maize Collection

Samples of all maize types grown in the 12 communities were collected. The names of the maize types identified in focus group discussions and during the survey were used as a guide for the collection. Forty ears per type were collected at random from the pile of harvested ears at the farmer's home. Dr. Juan José Hernández Casillas, an expert maize taxonomist and head of the INIFAP genebank, used the ears for racial classification. Samples of available commercial varieties were also purchased.

Experimental Grow-Outs

The sixth activity was an experimental grow-out of collected maize samples, samples of commercial varieties, and a representative sample of Tuxpeño landraces in the CIMMYT genebank. A trial was established in June 2002 and completed in December 2002 at INIFAP's Cotaxtla Experiment Station located in the state of Veracruz, Mexico. Morphological and agronomic data for several traits have been recorded and will be analyzed.

Chapter 3

The Study Area

The 12 communities included in this study are located in two highly contrasting regions: the coast of Oaxaca and La Frailesca, Chiapas (Figure 2) (here referred to simply as Oaxaca and Chiapas). Communities in Chiapas have better access to government-provided services and infrastructure than communities with a similar marginality level in Oaxaca. Farming activities in Chiapas are more market-oriented, and the region has received strong support from the state and federal governments, particularly for agricultural development. This region produces large maize surpluses that are exported to other parts of Mexico, but is still dominated by small-scale farmers who produce both for the market and their own consumption. There is an important dairy industry, and farmers can add value to their maize by using or selling it as animal feed. Over the years, the use of inputs and improved seed has been promoted through several government projects.

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

As an example of these differences, Table 1 compares key characteristics related to population, farming, maize production, income sources, and poverty between the two study areas. There is a much larger population in Oaxaca than in Chiapas, but

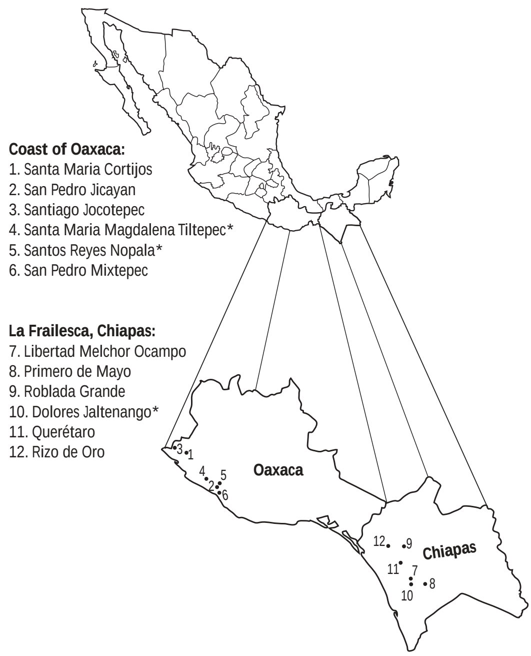

Figure 2. Map of the communities included in this study.
* Communities included in the case studies.

the farming area is much smaller; hence, there is stronger population pressure on the land in the former than the latter. Farming households in Oaxaca produce maize mainly for home consumption, using little hired labor and few fertilizers. Most households do not sell maize; on the contrary, they have to purchase additional maize for their own consumption. Cattle ownership is not very common, although those who do own cattle have a fair number of them. Many farmers work off their farms as hired laborers. Other sources of income are scarce, with less than one-fifth of farmers engaging in them.

Farming households in Chiapas, on the other hand, produce maize mainly for the market, although they also consume what they produce and employ much more hired labor and, certainly, more fertilizer than farmers in Oaxaca (almost four times as much!); almost no farmer needs to purchase additional maize for consumption. Cattle ownership is less common than in Oaxaca, both in terms of the number of households who own them and the average number of heads they own. A much lower percentage of farmers work as farmhands compared to Oaxaca, although a similar proportion have other sources of income outside their own farms. The next section discusses the differences in poverty between the two study areas.

Poverty

Poverty is pervasive throughout the study areas, even in the more commercialized and developed Chiapas. Poverty rates were calculated using data on household consumption obtained from the survey. This included data on both purchased and home-produced items, to which local prices for similar goods and services were imputed.[8] Two poverty lines, extreme poverty and poverty,[9] were constructed and used to define three groups: the extreme poor (expenditure below the extreme poverty line), the poor (expenditure

Table 1. Comparison of key characteristics of the two study areas

	Oaxaca	Chiapas
Total farming population	21,471	10,507
Number of households	3,539	1,994
Households where only Spanish is spoken (%)	34.5	94.3
Maize production		
Production objective (households):		
Home consumption only (%)	82.6	2.9
Market and home consumption (%)	17	95.4
Agricultural landholdings (average/hh in ha)	1.9	5.3
Use of hired labor (%)	27.1	60.5
Use of chemical fertilizers (%)[1]	45.3	99.4
Average application rate (kg N/ha)[1,2]	52.9	202.6
Households that sell maize (%)	27	98.8
Households that purchase maize (%)	64.5	8.4
Animal ownership		
Households that own cattle (%)	36.4	27.4
Number of cattle/household (average)[3]	10.9	8.5
Income sources		
Off-farm labor (%)	63.5	45
Non-farm labor (%)	17.6	19.8
Temporary migration (%)	16.7	14.1
Remittances (%)	10.6	13.6
Poverty indicators		
Number of farming households:		
Extreme poor	2,645	1,261
Poor	666	521
FTG poverty indices:		
Headcount index	0.80	0.72
Poverty gap	0.34	0.27
Severity of poverty index	0.17	0.13

1 Data based on one field per household in the sample.
2 Of those who applied fertilizers.
3 Of those who own cattle.

8 Per capita expenditure was calculated and adjusted to adult equivalents based on the weights used by Skoufias et al. (1999). Furthermore, household expenditure in Oaxaca was adjusted to make it equivalent to purchasing power in Chiapas because prices for similar goods were higher in Oaxaca than in Chiapas.

9 Poverty lines were developed according to the methodology of Guevara Sanginés et al. (2000). The extreme poverty line was defined as the expenditure necessary to purchase the COPLAMAR standard food basket, plus 27% more for basic non-food items (MX$ 415/capita/month in 2001). The poverty line differed from the extreme poverty line in that it increased the amount of non-food items to 125% of the cost of the food basket (MX$ 754.82/capita/month in 2001).

between the extreme poverty and the poverty line) and the non-poor (expenditure above the poverty line).

Most farming households in Oaxaca and Chiapas (74.7% and 63.2%, respectively) fall under the extreme poverty line. However, the rates of extreme poverty increase substantially on a population basis (Table 1), indicating that extremely poor households have, on average, more family members than the rest. Table 1 presents the FTG poverty measures (Foster et al. 1984) using the extreme poverty line as reference. The headcount index, the poverty gap, and the severity of poverty index show that there are more poor people, a wider poverty gap, and more extreme poverty in Oaxaca than in Chiapas. It is worth noting that although there are considerable differences between the two study areas in terms of population, farming, and income sources, they have similar poverty levels, indicating that poverty takes many forms and is not a monolithic phenomenon.

Poverty has multiple dimensions, of which consumption is only one. The qualitative work conducted as part of this study provided important insights into other poverty dimensions. Local indicators of poverty and wealth fall into several categories: material resources, culture, beliefs, and behavior. Resources are given the heaviest emphasis, with access to land and uses of land being the most significant; others include access to money, planting of other crops (e.g., coffee), performance of other activities besides agriculture, ownership of animals and implements, amount of family labor that can be mobilized, ability to speak Spanish, whether one receives remittances or not, and type of off-farm labor performed.[10]

The wealthiest people generally do not reside in the studied towns, though they may own farms nearby; more importantly, they are said not to cultivate maize. Nobody is considered wealthy just because they have large areas sown to maize. According to our informants, those who own 20 hectares of land or more dedicate only a small portion to maize. Other parameters that people use to distinguish social status are possessions, schools attended by the children, and clothes. The extreme poor are those who live on the outskirts of the village in overcrowded, precarious houses with dirt floors; they sleep on straw mats, cook on open fires, are dirty, wear no shoes, and dress in tatters.

Another aspect of poverty, as locally perceived, is cultural: indigenous roots indicate poverty. Indigenous people live on the margins of the community and have little land or money. Illiteracy and lack of Spanish fluency keep people in poverty by limiting their ability to find work outside the area. Finally, poverty is also related to beliefs, practices, and behavior. Wealthier families are thought to represent the best morals and practices: they are hardworking and frugal. They are also regarded as stuck-up, distrustful, and stingy. Families of average wealth are described as hardworking, but held back by the lack of access to some vital resource. The poorest have great difficulties; they have no money and no one to help them. They are perceived as hurting themselves by

[10] Many of the indicators of wealth and poverty identified in the qualitative work were included in the survey, and systematic information was elicited about them. These data were later used in combination with consumption data to develop a regression to predict the log of per capita consumption per household for each region (Appendix 2). These regressions were later included in the adoption model presented in Chapter 5.

wasting money from government programs on vices, and as perpetrators of domestic violence. Women cannot provide good homes for their families because they have to work, and their children cannot go to school for lack of money. In some communities, religious affiliation seems to matter; Evangelical Protestants, in particular, are said to be wealthy because they work hard and do not drink.

It is important to note that, with the exception of Nopala, Oaxaca, the most urbanized field site in the case studies, residents believe that all their fellow townspeople are poor. One implication of this is that one need not be overly concerned with targeting technology to the poor. Nonetheless, when researchers pressed the point, informants recognized gradations of poverty and did distinguish people of different levels based on the criteria cited above.

Vulnerability is another dimension of poverty emphasized in the qualitative work. The case studies revealed that farmers see maize as an extremely risky enterprise, albeit necessary for food security:

> *"…we need it to live; without it we don't eat. The worst thing is that you can never have security with maize because we never know what could happen. You are in the hands of God and cannot do anything about it. You have to suffer agricultural problems…caused by the rain or strong winds, just like the pests that attack the crops… It used to be you could leave your maize ears lying around and nobody would take them; not now. And you could work without using so much liquid [inputs]. That has changed, too."*

A number of factors related to agriculture and maize production make people vulnerable to poverty or to deepening poverty: 1) population growth, which puts pressure on the land; 2) resource-related pressures: lack of cash for investing in agriculture; "tired," hilly, eroded land; 3) the local economic system, including poor people's restricted access to markets and lack of stable wage work; 4) low educational level, illiteracy, speaking just an indigenous tongue (no Spanish); 5) falling coffee prices and low maize prices; 6) shocks: sudden, severe climatic events, human and animal health problems, too little or too much rain, and strong winds; 7) seasonal changes such as: people run out of maize and have to buy seed and invest in their fields just when they have the least money; the poor must work off-farm during the planting season and, as a result, do not tend their fields and produce low yields; also, due to a religious festival, the poor harvest their maize too early, before the ears are ready, and sell the grain before the price reaches its peak; and 8) human diseases: colds and flu make work more difficult. It should be noted that in both study areas climatic risks were considered the most serious vulnerability factor.

The institutional environment surrounding maize markets in Chiapas reveals and exacerbates social differences. For example, warehouses have minimum quantity and quality requirements that the poorest farmers cannot meet. Consequently, they must sell their production to intermediaries, better known as "*coyotes*," who are less demanding about quality and quantity, but pay much less than the warehouses. Though held in low esteem, *coyotes* are a necessary evil, for they pay cash up front, pick up the maize at the farmgate, and do not charge for transportation. They also provide loans for planting, and many farmers go into debt in order to plant.

Pests and diseases affect crops and large animals. Pests such as fall armyworm (“gusano cogollero,” *Spodoptera frugiperda*), wireworms (“gusano de alambre,” *Agriotes* spp.), and white grubs (“gallina ciega,” *Phyllophaga* spp.) were of utmost concern to residents of Chiapas. In Oaxaca, people mentioned pests such as raccoons, hummingbirds, skunks, and maize-eating domestic animals (such as hens, pigs, horses, and donkeys) that frequently invade fields and storage areas.

Livelihoods

Households in the two study areas have diversified livelihoods: they grow several crops, keep different types of animals, and participate in diverse off- and non-farm activities. Besides maize, they grow beans, squash, fruit trees, coffee, tomatoes, red peppers, sesame seed, hibiscus (*jamaica*), groundnuts, and cacao. All households in both study areas grow maize; most also grow beans, particularly in Chiapas. Households in Oaxaca grow a more diversified set of crops than those in Chiapas. Agricultural day labor is a common activity, particularly for the poor. Temporary migration, although not very common, is also associated with the poor. Relatively few households receive remittances or have non-farm skilled or semi-skilled jobs. Activities specific to women include food preparation, handicrafts, taking in wash (common among the poor), and running a small business (common among the non-poor poor).

An interesting aspect of livelihood strategies that emerged: though diverse economic activities are the norm in these communities, diversity varies with wealth. The wealthiest and poorest of people are said to engage in fewer activities: the wealthy specialize in a few high-earning activities and have less need to diversify because their primary activities are more stable. The poorest have few options and resources, and work at whatever they can. Families of average wealth maximize the diversity of their activities by engaging in the largest number of paid activities possible. Diversification notwithstanding, maize continues to play a crucial role in people’s livelihoods, especially of the poorest farmers.

Role of Maize in Farmers’ Livelihoods

Although maize is an important component of farmers’ livelihoods in both study areas, there are differences among them. More than three-quarters of farmers in Oaxaca grow maize for home consumption only, while almost all farmers in Chiapas grow maize both for home consumption and the market. Few farmers in either study area produce entirely for the market. In the past five years, more than half of Oaxacan farmers did not produce enough maize to meet their needs. Only about a third of farmers frequently sell maize, and most of those that do sell less than half of their production. Maize is sold mainly to families in the communities or, to a much lesser extent, local traders (the aforementioned *coyotes*).

In contrast, farmers in Chiapas are very commercialized. More than 90% produced surpluses in the past five years. Almost all sold maize; those that did sold more than half of what they produced. They sold mainly to the government, private businesses, and local traders, or a combination of them. Almost no one sold to other families in the community.

The price of maize varies between study areas. Maize is much more expensive (about 60% more on average) in Oaxaca than in Chiapas. There are also differences between purchasing and selling prices. Although maize is more expensive in Oaxaca, there is almost no difference between selling and purchasing prices; however, there are important differences in Chiapas, where buying maize is around 30% more expensive than selling it.[11] Hence, it is significantly cheaper for a household in Chiapas to produce its own maize than to sell and then have to buy additional grain. This may explain, to a certain extent, why in a commercialized system such as the one in Chiapas, producing maize for home consumption remains an important objective.

Differences in prices between the study areas are explained, at least in part, by differences in area planted and productivity. During the 2001 rainy season, sampled farmers in Oaxaca planted a total of 4,165 ha, while farmers in Chiapas planted more than twice as much: 9,039 ha. Furthermore, while yields in Oaxaca were frequently around 1.2 t/ha, in Chiapas they were around 2.7 t/ha—more than double. These numbers indicate a difference in overall production on the order of five times more in Chiapas than in Oaxaca! This would explain again why most farmers in Oaxaca have deficits and are heavily subsistence oriented, while almost all farmers in Chiapas, even the poor, are surplus producers who sell a high proportion of their harvest.

The qualitative work supports many of these findings. In Oaxaca, people grow maize mainly for personal consumption, and the poorest farmers depend on it for their food security: "We have maize for food. It is the only thing that we cannot do without in the house; we would suffer, and if we had to buy it, it would be a big expense." Growing maize enables them to use what little money they have on other items: "I don't earn enough money to buy maize, so I plant it so as not to have to buy it. When I sell to make a little money, it is to buy something else—for example, sugar, soap, whatever we need at home."

The less poor are not as dependent on maize production for their subsistence. Several said that wealthy people do not plant maize; they prefer to invest in other things and buy maize or tortillas. Some of the less poor go into partnerships or rent their fields. They also hire day workers from among the poorest people. If they have a surplus, they sell it within the community, often in their own stores.

Although people in Chiapas are mostly interested in selling their crops, maize cultivation assures basic subsistence and is particularly important for the poorer farmers. As an extreme-poor farmer in the village of Dolores explained, "It is necessary to take out the portion that is our food because there is no work; if we don't

11 The reasons for this difference are not clear. It may be that the local markets are thin, and traders incur high storage costs, as well as risks (not only physical storage costs, but also money tied to the product in the absence of efficient financial markets); hence, they demand a high premium.

plant, we starve.” Still, for many, maize is most important as a source of money. Although they reserve a portion of the grain for their annual consumption, people who are better off sell maize in large quantities. Large producers in Chiapas have trucks, shipping contacts, and enough money to buy other products.

Maize also plays important non-economic roles in people’s lives, though they sometimes have economic implications. For example, maize plays a role in the cargo system (also known as *mayordomía)*, a ritual cycle wherein people sponsor parties honoring a saint’s feast day. This especially affects the extreme poor. To pay for holiday expenses and have any hope of advancing in local society, the residents of Dolores sell “accelerated,” or immature, maize. Interrupting the maize cycle by harvesting early causes people to lose significant income.

A few farmers in Oaxaca said they planted maize because of tradition, which also colors their interpretation of the material benefits of maize. One man explained, “I cannot accept not planting, because when I was little this was my father’s job. So I can’t stop planting. When the maize ears are tender, you harvest whenever and whatever you want. If you have to buy, it isn’t the same.”

Chapter 4

History of Dissemination and Adaptation

Maize Germplasm

Farmers in both study areas plant numerous maize varieties, from hybrids to landraces. Different maize varieties were collected as part of this study, with a total of 126 samples assembled. Each sample represents a distinct type recognized by farmers in a community.[12] Table 2 shows the number of samples collected per region, along with their classification by a maize taxonomist, plus the average and maximum numbers of varieties sown by farmers (the latter data were taken from the survey). A larger number of samples was collected in Chiapas, where the amount of materials that can be traced to improved germplasm is substantially higher than in Oaxaca. However, many landraces were also collected there. The opposite is true in Oaxaca, where most samples were classified as landraces and a much lower number as containing improved germplasm. On average farmers plant more varieties in Chiapas than in Oaxaca, but the difference is small.

Table 2. Maize samples, their classification, and the average and maximum numbers of varieties sown by farmers in the study areas

	Oaxaca	Chiapas
Maize samples collected (no.)	57	69
Landraces	36	33
Carrying improved germplasm	11	36
Average number of varieties/farmer	1.2	1.5
Maximum number of varieties/farmer	3	5

The survey also elicited extensive information on the varieties planted, including their names, origin, history, and management. We classified maize varieties into five categories: hybrids, recycled hybrids, open-pollinated improved varieties (OPVs), creolized varieties, and landraces. Classification was based on: (1) the name provided by the farmer, (2) whether the farmer said the seed "came from a bag," (3) the number of years the seed had been used, (4) information on its origin from the farmer and from focus group discussions, and (5) classification by a maize taxonomist of samples collected from all communities in the study. Table 3 presents the specific criteria used for each category. It should be noted that classifying the maize types elicited from surveyed farmers entailed a certain degree of arbitrariness. As Morris et al. (1999) note, the dynamic nature of maize makes classifying maize varieties into distinct and well-defined categories difficult and somewhat arbitrary. However, classification is useful as long as the criteria used are workable, defensible, and consistent. The criteria defined above were applied

[12] The sampling strategy was to collect all the different maize types identified in each community. Maize types or varieties were identified during focus group discussions as well as from the survey, since collection occurred afterwards.

systematically, and we are confident that the classification is meaningful. It is the basis for the adoption and impact analyses presented below.

A key finding of the household case studies is that local categories of maize types are not the same as the ones defined above. People generally classify seeds that do not come in a new package as *criollo*, regardless of whether, according to formal definitions, they are recycled, creolized, or a landrace. In Oaxaca people distinguish between *criollo* maize and a variety. The latter includes all materials coming from programs of the federal Ministry of Agriculture (MOA). In Chiapas, farmers distinguish between *criollo* maize and seeds from a bag. Among bagged seeds, they distinguish between those from the MOA and hybrids or commercial seed supplied by agricultural supplies stores locally known as "*veterinarias*." In neither region do people distinguish between old or "original" *criollo* seeds—that is, landraces—and those that have been "criollo-ized" (*acriollados)* over time. Both types are called *criollos*.

In general, people do not define varieties so much as describe them in terms of their advantages and disadvantages. Only in Oaxaca did some people refer to *criollos* as original maize–i.e., a landrace. They have positive perceptions of these varieties; as one farmer revealed, "It is good, the first one that began to help us." People in Oaxaca generally have better knowledge of the characteristics of each variety, probably because they have a longer tradition of maize cultivation than is found in Chiapas.

People express varying degrees of confidence in different types of seed. They profess to have more confidence in *criollo* seed (i.e., the combined local category), because they know it: "We have confidence in it because we already know it, we have

Table 3. Criteria used to classify farmer-identified varieties into five categories

Category	Criteria
Hybrid	• Named provided by farmer is of a known hybrid • Seed "came from a bag;" first year planted • Focus group identified name as introduced to the community by government or commercial outlet • Maize taxonomist indicated sample with same name was of a hybrid or a recycled hybrid
Recycled hybrid	• Same as above, but farmer planted seed from previous harvest up to four years
Open-pollinated variety (OPV)	• Same as above, but name provided by farmer is of a known OPV • Seed planted for the first time or recycled up to four years
Creolized variety	• Any of the above, but farmer recycled seed for more than four years and up to fifteen
Landrace	• Name provided by farmer is of a known maize race (e.g., Zapalote, Tepecente, Olotillo) • No specific name (*maíz blanco*), but planted for many years by either the surveyed farmer or someone else in the community • Did not "come from a bag" • Focus group identified name as that of a local variety • Taxonomist indicated sample of the same name was a landrace

planted it before and have no doubts about it." Recycling (i.e., selecting seed from a previous harvest and replanting) is considered as creating creolized seed. Most people believe recycled or *acriollado* seeds become *criollos* in a few years. In Chiapas large-scale producers expressed their preference for *criollo* seed, although they plant improved varieties. Key to classification as a *criollo* is that the seed has been "acclimatized" to local soils (i.e., it has adapted to local soils). According to one farmer in Chiapas, "At first it was like a hybrid, but now it is *criollo*... It likes the soil. It has become acclimatized." When asked whether this process was what makes a variety *criollo*, another farmer said, "Yes, that is exactly what makes it *criollo*. After several seasons it adapts and will produce anywhere. It was planted once, and now it knows the land, and since the land is good, [it produces]."

Seed Sources

Farmers in both Oaxaca and Chiapas distinguished between maize grain and maize seed, although from a biological perspective they are the same. When farmers recycle seed, they subject it to rigorous selection. In farmer-to-farmer transactions, maize seed and maize grain show important price differentials. For example, landrace seed costs MX$ 3.88 / kg[13] in Oaxaca and MX$ 3.51 / kg in Chiapas, while landrace grain costs MX$ 2.41 and MX$ 1.82, respectively. According to informants in the case studies, farmers can obtain seed: (1) by selecting it from their own harvest, (2) through social networking (buying and selling, and exchanges with relatives, neighbors, and friends), (3) by purchasing it from the government through the *ejido*[14] commissary, (4) by purchasing it from *campesino* (small-scale farmer) organizations, (5) by purchasing it (at a greatly reduced price) through political campaigns, and (6) by purchasing it in *veterinarias* or seed stores.

The most common seed sources cited by all social groups in both study areas were the previous harvest and social networks. Data from the survey support these findings. During the 2001 rainy season, most farmers in Oaxaca planted seed from the previous harvest (61.4% of seed lots).[15] In Chiapas the number was much lower but still significant (39% of seed lots). The rest of the seed came from other farmers, the government, or local stores. In Oaxaca the most common outside sources of seed are farmers' social networks (family, friends, and neighbors), the government, and stores. In Chiapas, on the other hand, the government is the main source, followed by social networks and stores. These patterns illustrate the contrasting nature of maize production in the two study areas, with Oaxaca relying more on local seed sources and Chiapas more on outside sources, particularly the government. Social capital plays a key role in accessing seed in Oaxaca, but is much weaker in Chiapas.

The case studies found that a higher number of the extreme poor cite the previous harvest as a seed source compared to other groups, and that the least-poor farmers in Chiapas rely less on

13 The average exchange rate during the period field work was conducted was MX$9.25/US dollar.

14 The *ejido* refers to the land tenure system and the social organization associated with it. The *ejido* as a social organization refers to a community of peasants that received a land grant from the government under the Agrarian Reform.

15 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 " (Louette et al. 1997:24).

social networks.[16] In Oaxaca informants said that social networks allow people to help each other, are a cheaper source of seed than other alternatives, and give them the opportunity to see the seed growing in the field:

Sometimes the maize is unknown, and you don't trust it enough to buy it. Instead, you turn to your people because you see that their crop grows well and the ears are pretty. So you ask if they have some seed stored away, and you buy a bit for planting. You can't trust store-bought seed…. You have to see a variety growing in your neighbors' fields. If not, you don't buy it.

The informants did not remember the exact introduction and adaptation history of each variety, nor the sequence of variety replacements. But they were aware that the old *criollo* varieties have been replaced by improved ones introduced by government or other institutions. When asked if he remembered particular landraces that were planted years ago, one farmer in Chiapas said, "Yes, they had big ears, were tasty, and didn't need fertilizers to produce." When asked why they had been replaced, he answered:

> *…Other, better-selected seeds came along...that people said were better. [They got here] through institutions offering improved seeds, and the ones we had been planting for so long were abandoned…We heard about them through commercials that said, "Look, this seed is good." And since our land no longer wanted to produce as much with the seeds we already knew, we were encouraged to try them.*

Once inside a community, new seeds spread mainly through informal networks. Social networks are key to dissemination because people have more confidence in them than in the government. The networks also allow farmers to observe the new seeds growing in their neighbors' fields and to buy or trade for the best varieties (though they may sometimes receive them as a gift). In the opinion of producers in Chiapas, good guaranteed seed is expensive and sold by seed companies. Although considered the best, it is unaffordable to many farmers. In fact, people commonly define poverty partly by the type of seed a farmer uses. As an average-poor man put it, "Around here poor people are the ones who plant ordinary varieties."

The government has played an important role in supporting maize cultivation, especially among the less well-off farmers, through programs that have provided access to seed, credit for purchasing inputs, and technical support. These programs have encountered many problems, and the experience has influenced people's perceptions of the reliability of government support and the quality of government seed. Significantly, this has made people wary of using improved seed in general.

The MOA, the main promoter of improved seed in both study areas, manages two important programs: the Alliance for Agriculture (Alianza para el Campo) and the Agricultural Support Program (Programa de Apoyos al Campo, PROCAMPO). The former provides, among other things, subsidized seed from both the public and private sectors, through the Kilo por Kilo program. The latter provides farmers with a

16 A social network is the group of people—usually family, neighbors, and friends—with whom a person interacts regularly and has a long-term social relationship.

cash subsidy for the area they plant to certain crops, maize among them, provided they were already planting them during any of three crop seasons prior to August 1993 and had signed up for the program. Farmers may use PROCAMPO funds to purchase seed and agricultural inputs. Despite their official purpose, these programs, especially PROCAMPO, are viewed with distrust by farmers: many do not register their fields in the program because they feel its ultimate aim is to take their land away. Others say that the proferred subsidy is not sufficient to cover cultivation costs, though it does help purchase inputs—if provided on time.

Credit was identified as a serious constraint in Chiapas (in Oaxaca credit is just as difficult, or more, to access, but farmers did not think it much of a problem, presumably because there is less commercial farming). Government and private credit initiatives have been established, but various problems were identified. In Chiapas farmers said they did not have the collateral required by a government program. They also mentioned that Bancrisa (a bank) in the past had offered credit to purchase seed, but many farmers did not repay the loans, and the credits were suspended. Apparently Bancrisa still holds the farming certificates (which grant the usufruct of *ejido* land) of people who defaulted, preventing them from obtaining new loans elsewhere. Many do not have birth certificates, which are necessary to obtain loans. In general, people complain that to get any kind of support they must waste a lot of time and money dealing with bureaucracy and red tape. One extreme-poor farmer explained, "Here there are lots of people with mistakes on their birth certificates. I had the same problem, which kept me from getting a loan. Even when the commissary would like to lend a hand, he can't because the papers are not correct."

In both study areas, the *ejido* commissaries are the most important local link between government programs and farmers. The Kilo por Kilo seed is channeled through the *ejido* commissaries, who have become an important seed source. Most improved seed used by *ejido* producers comes in inexpensive technological packages. These packages are, and have been, the principal source of improved seed for our case study households, although they are not the most popular. The quality of the seed is often poor, and farmers tell of seed rotting in the bag or in the field. An agronomist working in the region explained that government seed is poor because municipal governments provide only cheap seed that is poorly adapted to local soils.

Another problem common to both study areas is untimely seed availability–for example, when it is too late to plant: "We have no faith in the government now, because they don't come through on what they promise…the support comes so late that nothing can be done. …For example, PROCAMPO seed arrives after harvest, when you don't need it anymore. …Here we are waiting, and when the seed finally arrives, the rains have come and gone."

Farmers in communities in both study areas expressed a strong need for technical assistance, but also a lack of faith in government motives and reliability:

> *They recommended people who sell seed, but we need them to come before planting time. When we clear the land for planting…we need someone to come and study the soils to know about the pests… We need to know what kind of insecticide to spray…People have died*

because they got insecticide on them…Well, later some technicians from the Ministry came by, but at the wrong time, when we no longer needed them. I think they come only so that we can get to know them, but when we need their advice, we never see them.

Politics also makes it way into seed distribution. A common complaint is that government authorities distribute seed unfairly. Farmers in a Chiapas community had this to say about the influence of political parties: "The commissary gives the seed to his group of people and sells what is left over to the townspeople. He secretly calls his people and writes their names on the list, especially those who belong to the PRI." (PRI stands for Partido Revolucionario Institucional, Institutional Revolutionary Party, until 2000 the dominant political party in Mexico, and still strong at the local level.) Seed is also distributed through political campaigns—e.g., improved seed is given to party supporters either as a gift or at a low price.

Complaints about politics are also heard regarding agricultural support services in general. In Chiapas, the poorest people complain that support is given mainly to those close to the authorities. Another problem frequently attributed to politics (though it may also relate to economics) is that government programs stay in regional centers and do not reach small towns.

In Chiapas, improved seed (which is expensive) can be obtained through membership in regional *campesino* groups. In one community, this type of organization provides government help such as subsidized fertilizers and herbicides, seed at affordable prices, credit, and soil analyses. The organization has created high hopes, but the help it provides remains inaccessible to poorer farmers for many reasons. For example, the price of soil analysis is relatively high, and recommended seed is expensive. In addition, the organization is difficult to join. To do so, one must meet certain requirements, and membership is achieved only after a long period of attending meetings and paying dues. However, people who achieve it claim membership is worth the effort.

Seed Management and Seed Flows

Seed recycled from one's own or another farmer's harvest is the most important seed source, even to the more commercialized producers of La Frailesca. Beyond its value as a seed source, recycling has important genetic implications for the maize varieties farmers plant. Varieties change under farmer selection. By selecting the plants and, hence, the genes that are passed from one generation to the next, farmers play a fundamental role in shaping the genetic structure of their varieties.

Our case studies revealed seed recycling is a widespread practice in both study areas. As noted earlier, people see recycling as a process through which seeds become *criollo*–that is, they become adapted to local soils after successive plantings. When people are happy with their harvest, they select and store seed from it. Some farmers consider it wasteful not to plant the seed they harvest. There is also the notion that "it is better to choose my own seed grain, the one I like" rather than buy bag seed that carries unknown traits. Farmers also think seed is too expensive to buy every year. In fact, we did not find a single farmer in either community who bought all his seed every year.

Nonetheless, residents of Oaxaca are more likely to recycle seed than those in Chiapas, and they also buy seed from government and informal networks less often. When the extreme poor plant maize from a bag, generally it is because the seed was either free or cheap, and obtained through a government program.

Though all farmers recycle, poorer case study participants were more likely to than richer ones. Recycling gives the poor access to improved varieties whose original seed they could not afford. However, some less-poor farmers prefer to plant recycled, improved seed obtained from a neighbor who planted seed from a bag. One farmer from La Frailesca who had planted Pioneer seed from a bag said he later selected seed from his harvest, which became *criollo* maize that was better for planting. According to another informant in Chiapas, farmers "buy their bag and if the seed yields well, they keep planting it as long as it produces."

The number of years that farmers recycle varies between study areas: approximately 4-5 years among case study informants in Chiapas and longer in Oaxaca. An extreme-poor farmer there claimed he planted an improved variety for 12-16 years because it "gave good results." Farmers do not distinguish between seed that has just undergone this process and seed long in use, for they feel it is possible to "creolize" or adapt any seed and do not believe replanting has negative consequences. As a farmer in Chiapas told us, "Well, the agricultural technician says you shouldn't plant this way, but I do anyway–and lots of other folks do too." Another farmer explained that "though they claim the seed won't produce the next year, I think it will. All seeds have to produce: it's their nature. Of course, you have to take care of them with fertilizers and insecticides." A third (average-poor) farmer was more skeptical: "They tell us that hybrids will not produce from one year to the next. But I think this is a lie to help the seed companies make money." Many farmers believe that planting seed recycled by their neighbors is a way to improve their harvest. When 20 *ejido* members in a case study village in Chiapas obtained a new variety, most of our informants stated they intended to buy seed from them the following year.

When asked why farmers preferred to recycle, one explained, "Because we always have and, like I told you, we can't spend a lot on seed. Also, this way is safer because we've seen how the seed produces on the land around here". To illustrate the benefits of recycling, this farmer compared it to a situation where fieldworkers and villagers do not know each other. He said, "After several visits, they come to know each other and overcome their lack of trust. Later the fieldworkers can count on lots of friends in this place."

Farmers recognize that seed degenerates over the years. According to an average-poor farmer in Oaxaca, "We change when the soil demands it. Sometimes the land just doesn't want the same seed, because it has degenerated. Since we don't buy seed each year from the programs, we buy it from friends, like the *compadre* who has planted it before." Because people observe other farmers' fields and see results, everybody buys or trades seed as well. As one man explained, "Sometimes, who knows what's wrong with the seed–it just doesn't want to perform. So you switch to another, even though it is of the same strain, or just exchange it for something else."

Another way farmers shape the genetic structure of their germplasm is by fostering gene flow among different varieties, which has been documented in other parts of Mexico (Aguirre-Gómez 1999; Bellon and Berthaud 2001). In Oaxaca, farmers mixed externally acquired seed into 8.9% of their seed lots in the course of planting, while in La Frailesca this happened in 7.8% of seed lots. In this study, we considered that a farmer mixed seed if he added seed from a different variety or seed source to the seed lot that he planted. Later, during pollen release, the resulting (different) plants are very likely to pollinate one another. Farmers furnished other evidence that suggests gene flow: in Oaxaca they mentioned that in 2001 they gave seed to other farmers (through exchange, sale, etc.) from 26.4% of their seed lots, while receiving seed from others for 29.7% of the seed lots they planted. These figures were much lower in Chiapas (7.8% and 5.5%, respectively), which indicates that farmers in that study area play a role in shaping their germplasm, albeit a more limited one than their counterparts in Oaxaca.

During the case studies, we observed different maize planting systems and collected information to learn how creolization may occur. Many *ejido* farmers plant their crops on land having different slopes; the end result is that each variety grows under different conditions. Although most farmers will plant just two varieties, some plant more. In Chiapas, those who engage in the highest level of commercial maize production keep their fields separate and plant only one variety to avoid contaminating the ears. However, we also found farmers who plant more than one variety in the same plot, with little or no separation among them. This planting mode produces a mixture of maize, which is not considered a problem, as it is for household use; deformed or mottled ears are used for feed.

Farmers use not just different varieties, but also different planting dates, and combine them, for several reasons. First, they cannot plant everything at once. Second, this means tender ears for eating on the cob are available at different times of year. As an extreme-poor farmer from Tiltepec explained, “Early maize produces in less time. You plant it and maybe in two and a half months, it is already producing. You plant it to support yourself more quickly. Early maize is for eating on the cob; the other is saved for later use.” The third reason for using different planting dates is to minimize the risk of total loss.

As for using different varieties, one of the less-poor farmers from Nopala, Oaxaca, commented, “If one variety doesn’t produce well, the other might; if both produce, the harvest is good. In one plot we plant the new maize and in another, the proven one.” However, the poorer the farmer (for example, with only one small plot), the less inclined he is to risk trying a new variety. Finally, planting different varieties ensures farmers will get different characteristics for different objectives–i.e., for household consumption (immediate or long term), or for sale in bulk or piecemeal. A farmer from Querétaro, Chiapas, said that he liked to plant *criollo* seed because of its flavor and lower cost, but that he also needs to produce white maize for sale.

Regarding the deliberate crossing of maize varieties, it appears that most farmers have limited knowledge about the process.

However, farmers do cross maize, either intentionally or by accident. In Chiapas, they know that a maize crop is always purest in the center of a plot, and that mixed grains of different varieties are found on the borders. They are not very knowledgeable about the characteristics of different kinds of maize. They know that maize plants are both male and female; they learned this from talks given by CIMMYT researchers during this fieldwork, but it is not clear how much they understood. They know that the maize can be changed or contaminated when seeds are mixed, but they do not do so intentionally. They do not know how to cross-fertilize maize plants.

People on the coast of Oaxaca know more about maize reproduction. According to an agricultural technician in Nopala, Oaxaca, some *campesinos* there, especially the older ones, know how to improve their *criollo* seed. Farmers said they crossed "Tablita" with "Enano" by alternating rows of the two varieties. When asked what seed he planted, an extreme-poor farmer from Nopala explained, "We call it Enano [it was actually V534, an open-pollinated improved variety], but we started crossing it with a *criollo*. At first the husk didn't close… We planted it close together and now it closes fine." He said he bought the seed eight years ago. Farmers call the resulting variety Enano Grande and describe it as a *criollo* variety that used to be improved: "The Enano, when it was a variety—that's what they call the improved ones—the plant was small and so were the ears. Now they are bigger." Enano Grande was crossed with "Tepecente" or "Tabla." One of the extreme-poor informants said he intended to follow the example of his friends who crossed this maize:

> *That improved maize—the Enano—is very pretty, but when it rains a lot it rots. Yet when it produces, it's very pretty, though the plant is short. I planted it, but later I stopped. This year I liked it when I saw it in some of my friends' fields. I asked them what it was, and they said it was Enano. So this year I'm going to plant half Tablita and half Enano because my friends* [whose fields he saw and liked] *made a cross. That's why their plants and their maize are so pretty*.

We learned that after a visit by our research team, a group of *ejido* farmers tried crossing to improve their maize.

Farmers in Oaxaca tend to know more about this process than farmers in Chiapas, probably because Oaxaca has a longer maize-cultivating tradition than Chiapas. Also, the offices of the Ministry of Agriculture, with eight technicians and demonstration plots, are in Nopala, Oaxaca. An extreme-poor farmer from Nopala shows what he knows:

> *A year ago, I planted the maize we call Tablita in a plot by itself and in another together with another variety. If now I cross it with 526, half the grains are yellowish, and the ear is a little bit narrower. This year I planted it the same way, but with only a little 526 to see if it continues the same. I also planted it together with 534 to see how that works out…What happened* [when 526 was crossed with Tablita] *was I got some yellow ears and the maize became stonger. That's what we want—to cross a* criollo *with a variety to make it more resistant, so that it doesn't rot.*

When asked whether there were many people in Nopala who cross their varieties with improved ones, he said, "Yes. Some do it by accident, and others actually make crosses. We got together with *señor* Nicho and other people from La Cañada to plant several varieties together–just to see if they would cross." However, not everyone crosses maize varieties intentionally, nor do they know how to do it. As one key informant said, "It is not something they do consciously. Not many know how." Many farmers realize a cross has occurred when they notice a change in kernel color or plant height as a result of having planted two varieties together:

> *I have observed in the field that the maize comes up like one of the plants growing next to it. Look in the middle of the field and you find seed that looks just like Enano or Zapalote, because in Tiltepec some people still save Zapalote and yellow and white Tepecente. I notice because the ears come out yellow mixed with white, or some are smaller and others bigger. That's what we call a maize cross. We don't know why it happens, but it does.*

In Oaxaca, improved varieties are generally not perceived as being more labor-intensive than *criollos*. Today people think both the improved and *criollo* varieties require fertilizers and pesticides. They make no mention of using different practices for improved varieties, such as crop spacing, furrow spacing, and number of grains deposited in each hole. And when they do use improved varieties, they do not plant or fertilize them according to instructions. Farmers will often sow more than one seed per hole when they plant *criollos* and, sometimes, improved varieties, due to a concern over low germination and because they do not believe the technical recommendation of one seed per hole.

In Chiapas, improved varieties are perceived by farmers as requiring more work—for example, three passes to apply fertilizer and pesticides—and more care, because they are supposed to be planted closer together, one seed per hole (a recommendation most farmers doubt). As in Oaxaca, farmers in Chiapas do not always follow instructions. In fact, when a maize variety begins to degenerate, some people think that planting more seeds in each hole will correct the problem. Farmers in Chiapas also believe herbicides and synthetic fertilizers save labor in the fields. Perceptions about the amount of labor needed for improved varieties have not been used as an argument against improved varieties in the communities studied.

Chapter 5

Adoption

Extent of Planting by Maize Type

The relative area planted to each of the five maize germplasm types and the number of farmers who sow them vary in the two study areas (Table 4). Landraces are predominant in Oaxaca, followed by creolized varieties. The importance of creolized varieties is very similar across poverty groups. Few farmers planted improved germplasm, especially hybrids, and those who did planted them in small areas. The use of hybrids and recycled hybrids is most common among the non-poor, while the use of landraces, though they are predominant, is lowest among the non-poor. In contrast, in Chiapas the use of improved germplasm and especially hybrids is predominant. Improved maize types are planted by all farmers, particularly the non-poor. All poverty groups also plant creolized varieties and landraces. Creolized varieties are the single, most widely planted maize type in terms of relative area and number of farmers, and are planted in similar proportions by all poverty groups. Despite the widespread adoption of improved germplasm, landraces occupy more than one-fifth of the area planted to maize and are planted by more than one-fourth of farmers, particularly poor ones. The importance of landraces decreases as poverty level decreases. In both study areas (although on

Table 4. Distribution of five germplasm types by area and number of farmers

	Extreme-poor		Poor		Non-poor		Total	
Coast of Oaxaca	**area (ha)**	**farmers**	**area (ha)**	**farmers**	**area (ha)**	**farmers**	**area (ha)**	**farmers**
Total	3,011.67	2,645	833.01	666	320.58	228	4,165.26	3,539
Relative distribution (%)								
Hybrids	1.5	3.1	0.0	0.00	7.1	6.7	1.6	2.7
Recycled hybrids	2.0	3.1	8.5	8.7	12.2	13.3	4.1	4.8
OPVs	7.0	7.0	2.0	2.8	2.5	8.1	5.7	6.3
Creolized varieties	14.3	10.4	12.8	15.4	24.2	20.0	14.8	12.0
Landraces	75.2	84.2	76.7	85.3	53.9	66.7	73.9	83.3
La Frailesca, Chiapas	**area (ha)**	**farmers**	**area (ha)**	**farmers**	**area (ha)**	**farmers**	**area (ha)**	**farmers**
Total	**5,789.36**	**1,261**	**2,213.81**	**521**	**1,035.85**	**212**	**9,039.03**	**1,994**
Hybrids	19.8	30.9	22.2	31.1	63.3	54.8	25.3	33.5
Recycled hybrids	8.8	9.9	18.5	26.0	3.9	17.5	10.6	14.9
OPVs	20.0	33.1	12.8	22.8	4.3	10.5	16.4	28.0
Creolized varieties	26.6	36.7	31.8	38.8	25.3	37.6	27.7	37.4
Landraces	24.9	32.6	14.8	10.3	3.1	11.1	19.9	24.5

very different scales), there seems to be a trend towards increased use of hybrids and improved germplasm as poverty decreases, and a reverse trend for landraces. Creolized varieties seem, however, neutral to poverty level in both areas.

Factors Explaining Adoption

Adoption is a complex process, affected by numerous factors and circumstances. Factors influencing maize adoption can be grouped into five categories: (1) adaptation; (2) management intensity; (3) cultural values associated with maize consumption; (4) risk; and (5) participation in the regional / national economy.

Adaptation refers to how the germplasm performs in a particular agroecological environment. Improved varieties are bred and tested on experiment stations that in theory reflect conditions in the target environments, but this is not always the case. Varieties are usually bred for wide adaptation (i.e., they are supposed to perform well in diverse environments). Landraces, on the other hand, have evolved in particular environments, to which they are well adapted. As discussed above, farmers are very skeptical of the adaptation of improved varieties and have great confidence in the adaptation of local ones (*criollos*), creolization being a process by which improved varieties become adapted to their conditions. Hence, one would expect improved varieties to be planted only in certain environments (usually the most favorable), and landraces—which are adapted to all local environments—to be planted only in more marginal conditions, with creolized varieties somewhere in between.

Management intensity refers to the amount and timing of input application required for a variety to perform well. A management-intensive variety requires large amounts of inputs and strict adherance to planting date, timely weeding, and fertilizer application; otherwise its performance is drastically diminished. A non-management-intensive variety can withstand delays in these operations and responds to low input levels without dramatically reducing its performance. Most small-scale farmers perceive improved maize varieties as management-intensive, and landraces as non-intensive. Improved varieties are usually bred for optimal conditions,[17] including high input levels and appropriate agronomic practices, while landraces have evolved under sub-optimal management conditions, such as late planting, high weed infestation, and low inputs.

Maize cultivation in Mexico is not just an economic activity. There are strong cultural values and preferences associated with it. Small-scale farmers, particularly indigenous ones, have their preferred traits, especially for culinary and ritual purposes. As shown in previous sections, there is a strong—even emotional—link to maize in the study areas. Landraces that have evolved there reflect farmers' values and preferences. Since these preferences are highly subjective and difficult for breeders to select for, one would not expect improved varieties to possess the special traits farmers value.

[17] Improved varieties can also be bred for marginal conditions and sub-optimal management, such as low inputs and high incidence of drought and weeds, as CIMMYT is currently doing in Eastern and Southern Africa.

As shown before, maize cultivation is a risky endeavor, particularly under the rainfed conditions faced by these farmers. Risk is related not only to biotic and abiotic stresses associated with maize cultivation, but also to farmers' knowledge and understanding of how different varieties perform under their conditions. Farmers emphasized trust and knowledge as two important advantages *criollos* have over introduced improved germplasm. Creolization could be viewed as a process that develops farmers' trust in germplasm. Trustworthy germplasm is particularly important when one is very vulnerable. Although improved varieties may not necessarily perform poorly under some of these stresses;[18] they are perceived as being riskier because they are less well-known and well-understood than *criollos*. Results of our case studies support this point.

Participation in the regional/national economy gives farmers the opportunity to sell their surplus production, acquire seed of improved varieties, purchase inputs, access other income-generating opportunities, and purchase cheaper consumer goods—including maize. Increased participation should foster the adoption of improved varieties and, to a lesser extent, of creolized varieties, by providing access to seed and inputs, and a market for surpluses, since improved varieties and, to a lesser degree, creolized varieties are supposed to be higher yielding and more responsive to inputs than landraces.

Actual adoption of a particular type of germplasm by a farming household depends on the interaction between the above-mentioned factors and the assets controlled by the household and the conditions it faces. To examine actual adoption, we made these factors operational through the use of several variables measured in the survey. The variables were used in a regression framework to explain the area planted to the five different types of maize germplasm defined in the section on maize germplasm (p. 17). In each region, two regression models were estimated for each maize type, although in some cases two or more types were collapsed into one due to the small number of observations for each type.[19] The regression models were based on an economic adoption model and its econometric estimation, developed by Bellon and Taylor (1993). The reason for estimating two models was to test whether land quality is a significant factor influencing farmer adoption. The first model (A) does not account for land quality effects (all land qualities are combined simply into total landholdings). In the second model (B), land quality is disaggregated into five land types (discussed below). If land quality effects are not important, both models should be equal; if they are not equal, then land quality effects help to explain adoption. To test for this, a likelihood ratio test of both models was performed and reported.[20]

18 As will be shown, improved varieties have better resistance to lodging, a key source of risk, due to their shorter stature.
19 Hybrids, recycled hybrids, and OPVs were aggregated in Oaxaca, while recycled hybrids and OPVs were aggregated in Chiapas.
20 If the models are statistically different, then the results from the model where land quality is disaggregated (B) is discussed; otherwise, results from the model that does not account for land quality effects (A) are discussed, since it is the more parsimonious of the two.

The econometric analysis of adoption decisions is complicated because the dependent variables (area planted to different maize types) are censored at zero—that is, there are a number of zero-adopters for each maize type. Failure to correct for censorship may result in biased and inconsistent estimates. To correct for this, we used Amemiya's extension of Heckman's two-step estimator (Amemiya 1974). Amemiya's estimator controls for the endogeneity of the discrete adoption decision while estimating the equations for land area under different maize types. Variables included in the regressions are age, household language, percentage of indigenous speakers in the community, household expenditure, source of labor used in maize production, land quality, fragmentation,[21] access to extension services, participation in government programs, and distance to the main town (Table 5).[22]

It should be pointed out that household expenditure is endogenous. Estimated for each region was a regression of the log of expenditure as a dependent variable against a set of explanatory variables associated with local perceptions of poverty and other measures of marginality thought not to affect adoption decisions (Appendix 2). The predicted values of these regressions were used in the adoption regressions. Table 6 presents the hypothesized relationships between each variable and the adoption of each maize germplasm type. The rationales for the hypothesized relationships are presented below.

A farmer's age is an indicator of risk attitudes. Older farmers may be more conservative and risk-averse. They may also have better knowledge of local landraces and be more willing to plant them and, to a lesser extent, creolized varieties (both of which are more trusted) than improved varieties. Younger farmers may be more willing to take risks and plant less trusted varieties.

Household language is an indicator of cultural identity and ability to interact with the regional and national economies. Speakers of indigenous languages are more likely to attach stronger cultural values to maize consumption than exclusive Spanish speakers; hence, they may prefer to plant landraces rather than improved and, possibly, creolized varieties. On the other hand, exclusive Spanish speakers may interact better with the regional and national economy and, hence, be more interested in growing improved varieties and, to a lesser extent, creolized varieties. This variable, however, was not included in the adoption regressions for Chiapas, where almost all households speak only Spanish and there is a longer history of integration into the national culture and economy than in Oaxaca.

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21 The number of plots into which the landholdings managed by one farmer are divided.

22 Several reviewers questioned whether some of these variables were endogenous, e.g., use of family labor only, access to agricultural extension, participation in government programs, and landholding fragmentation. Regarding the first three variables, the information elicited referred to a period of five years prior to the year when the decision to plant a variety was measured; thus regarding specific planting decisions these variables were fixed. As for fragmentation, it refers to the whole farm during the period before actual planting, also fixed before the measurement. The only truly endogenous variable, expenditure, is explained in the text. Some reviewers questioned whether participation in government programs induced a systematic bias in the sample, since people may not have been eligible to participate. Based on our knowledge of these farmers, all were eligible to participate in these programs, and if they did not, it was because they chose not to. Particularly for PROCAMPO, farmers said many did not participate because they were either absent or sick when registration took place or because they were afraid the government would tax their land or take it away. Clearly these factors are idiosyncratic rather than systematic. In any case, participation in these programs was very high.

Table 5. Description of variables used in adoption regressions for Oaxaca and Chiapas, Mexico

Variables	Definitions[1]	Oaxaca	Chiapas	Significance
Dependent variables				
Hybrids	Area planted to hybrids	0.025	1.144	****
Recycled hybrids and OPVs	Area planted to recycled hybrids and improved open-pollinated varieties (OPVs)	0.133	1.229	****
Improved varieties	Area planted to improved varieties (hybrids, recycled hybrids, and OPVs)	0.158	2.373	****
Creolized varieties	Area planted to creolized varieties	0.247	1.236	****
Landraces	Area planted to landraces	0.875	1.014	
Independent variables				
Total area	Total farm area[2]	2.138	5.365	****
Land type 1	Area under plow agriculture–best quality	0.298	0.475	
Land type 2	Area under plow agriculture–fair quality	0.304	0.565	
Land type 3	Area under *pedregal*[3] agriculture–best quality	0.808	1.600	****
Land type 4	Area under *pedregal*[3] agriculture–fair quality	0.623	2.533	****
Land type 5	Area of worst quality land	0.106	0.191	
Fragmentation	Number of plots owned by household	1.129	1.975	****
Age	Farmer's age (years)	50.01	48.66	
Household language	1 if household mother tongue is Spanish; 0 if otherwise	0.436	0.938	****
% indigenous language	Percentage of speakers of an indigenous language above 5 years old in the locality	34.003	1.883	****
Expenditure	Predicted expenditure (pesos/capita/month)	377.75	388.94	
Family labor only	1 if household only used family labor to produce maize in past 5 years; 0 if otherwise	0.718	0.401	++++
Extension	1 if household had contact with extension in the past 5 years; 0 if otherwise	0.123	0.160	
Kilo por Kilo	1 if household participated in the Kilo por Kilo government program in past 5 years; 0 if otherwise	0.258	0.358	++
PROCAMPO	1 if household participated in the PROCAMPO government program in past 5 years; 0 if otherwise	0.736	0.840	**
Distance	Distance to main town in travel minutes	74	78	

[1] Means for continuous variables, and fractions for dummy variables; all areas in hectares.
[2] These unweighted averages differ from the weighted averages in Table 1.
[3] In the *pedregal* system, land is not plowed, and planting is done with a dibble stick.

*, **, ***, **** significant at the .10, .05, .01, .001 levels, respectively, for a 2-tailed t-test.
+, ++, +++, ++++ significant at the .10, .05, .01, .001 levels, respectively, for a Chi-square test of independence.

Table 6. Hypothesized relationships between variables and adoption

Variables	Improved varieties	Creolized varieties	Landraces
Age	-	+	+
Household language-indigenous (culture)	-	-	+
Household language-Spanish only (interaction regional/national economy)	+	+	
% speakers of an indigenous language in the community	-		+
Household expenditure	+	-	-
Use of family labor only	-	+	+
Land quality	+		-
Landholding fragmentation (adaptation)	-	+	+
Landholding fragmentation (management intensity)	-	+	+
Landholding fragmentation (risk)	+		
Extension	+	+	
"Kilo por kilo" program	+	+	
PROCAMPO program	+		
Distance to nodal town	-		+

The percentage of indigenous speakers in a community is another indicator of cultural identity. Although they may no longer speak an indigenous tongue, many farmers still attach strong cultural values to maize consumption. One would expect that in communities with a higher percentage of indigenous speakers, even non-speakers would be more likely to share these cultural values than in communities where no indigenous languages are spoken. Where there is a higher percentage of indigenous speakers, landraces can be expected to be more highly valued and, hence, planted over larger areas.

Household expenditure was used as a proxy for welfare and poverty.[23] Most farming households in these study areas are either poor or extremely poor; however, there may be differences among them. The poorer the household (and the lower the expenditure), the less it may be able to afford inputs and seeds, and the less likely it is to take risks. Hence, one would expect that as expenditure increases (or decreases), households would plant more improved varieties (or more landraces). Given the key hypothesis of this study, one would expect poorer farmers to be more likely to adopt creolized varieties than the less-poor ones.

Farmers who rely exclusively on family labor to produce maize may be more constrained to deal with management-intensive varieties than farmers who can hire field laborers. Hence, the former may be more likely to plant a larger area to landraces / creolized varieties, while the latter would probably plant a larger area to improved varieties.

Land quality is an indicator of adaptation. Not all land is equal. Soil fertility varies, and stoniness and slope affect how the crop is managed. Landholdings were classified into five categories depending on the production system and farmers' assessment of land quality (very good, good, poor). Production system refers to whether farmers plow the land (locally known as *arado*) or not (locally known as *pedregal*). The production system is correlated with a field's slope and stoniness; those in *arado* are flatter and with low stoniness, while *pedregal* plots are either on steeper slopes or on flatter land with high stoniness. Improved varieties are usually planted on the best lands and landraces on more marginal lands, with creolized varieties somewhere in the middle.[24]

Landholding fragmentation—the number of plots a farm is divided into—is an indicator of adaptation, management intensity, and risk management. The greater the fragmentation, the greater the number of different environments a farmer has to cope with, and the more important well adapted local varieties are likely to be. Hence, greater fragmentation can be expected to foster greater use of landraces and / or creolized varieties. Fragmentation can also make coordinating and mobilizing labor more difficult. The more (less) fragmentation the more (less) difficult it may be to grow management-intensive varieties; hence the less (more) likely it is that farmers will plant improved varieties. Fragmentation may also reduce the risk of crop failure—e.g., a pest may affect the crop

23 Expenditure is obviously only a partial indicator of welfare, since it does not take into account many other important dimensions of welfare. It is, however, easy to measure and widely accepted, even with these limitations.

24 In other papers (Bellon and Taylor 1993; Bellon and Risopoulos 2001), local soil taxonomy was used to make the concept of land quality operational, but only one community was studied. Although this information was collected, it was not used because categories varied across communities and were not necessarily comparable.

in one plot but not in another. Fragmented landholdings may allow farmers to take risks. Thus, to the extent that improved varieties are perceived as riskier, fragmentation should foster their adoption.

Participation in government programs is an important way for farmers to link up with the regional and national economies. These programs provide farmers with inputs, financing, and specialized knowledge, and probably influence farmers' planting decisions. Kilo por Kilo and PROCAMPO were two important government programs in the study areas (see p. 18). Kilo por Kilo provided improved seed and gave farmers access to PROCAMPO money that they could use to purchase inputs. Some farmers also received extension services through these programs.[25] One would expect participation in these programs to foster adoption of improved varieties through access to seed, inputs, and specialized knowledge—farmers' negative opinion of government services notwithstanding.

The distance between a community and a key nodal town was included as an indicator of potential linkages to the regional and national economies. The underlying rationale is that farmers in communities closer to a key town can more easily interact with the regional and national economies, since transportation costs are probably lower. They are also more likely to plant improved and / or creolized varieties, while those farther away may have to rely more on landraces.

Results from Oaxaca

Results of the estimations for Oaxaca are discussed below. For the adoption of improved varieties, the results show that land quality does not affect adoption decisions (the likelihood ratio test is not significant); however, fragmentation, farmer's age, and exclusive use of family labor do (Table 7). The sign of fragmentation is compatible with the hypothesis that it reduces risk and hence fosters the adoption of improved varieties. Most households plant maize in only one field, using only one variety. Extra fields give farmers the opportunity to plant more varieties with less overall risk because the stresses that affect one field may not affect the others. Results for farmer's age contradict the risk hypothesis, since older farmers tend to plant a larger area to these varieties. Older farmers may be less risk-averse or, alternatively, improved varieties may be less risky than expected. However, the qualitative data stress farmers' lack of confidence and trust in these varieties and the perception of riskiness associated with them; hence, the first alternative is more plausible. Farming households that rely on family labor only tend to plant a smaller area to improved varieties, which is compatible with the hypothesis that these varieties may be management-intensive.

For the adoption of creolized varieties (Table 8), results show that model B is statistically different from model A, which indicates that land quality does play a role in adoption. Household language, percentage of indigenous speakers in the community, and

[25] To make the variables exogenous, participation in these programs was measured based on the five years prior to this study. Although in our sampling design we tried to include communities with and without participation in Kilo por Kilo, the data show that all communities had access to this program and to PROCAMPO. However, not all farmers within a community participated in the programs or had access to extension services.

Table 7. Regression results of two adoption models for improved varieties, Coast of Oaxaca

	Model A			Model B		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Total area	-0.008	0.009				
Land type 1				-0.019	0.018	
Land type 2				0.001	0.014	
Land type 3				0.024	0.017	
Land type 4				-0.024	0.016	
Land type 5				-0.016	0.014	
Fragmentation	0.194	0.046	****	0.194	0.049	****
Age	0.002	0.001	*	0.002	0.001	*
Household language	0.029	0.050		0.043	0.052	
% indigenous language	0.0003	0.001		0.0004	0.001	
Expenditure	0.00004	0.00006		0.00003	0.00005	
Family labor only	-0.131	0.039	***	-0.133	0.040	****
Extension	0.024	0.053		0.025	0.055	
Kilo por Kilo	-0.016	0.044		-0.008	0.045	
PROCAMPO	-0.056	0.040		-0.055	0.041	
Distance	0.001	0.001		0.001	0.001	
Inverse Mills Ratio	0.566	0.026	****	0.565	0.027	****
Constant	-0.133	0.124		-0.128	0.128	
Log likelihood	26.598			25.587		
Log likelihood ratio test[1]	2.023 (4 df)					

[1] Log likelihood ratio corresponding to a test that the two regressions are equal.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.

Table 8. Regression results of adoption models for creolized varieties, Coast of Oaxaca

	Model A			Model B		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Total area	0.223	0.039	****			
Land type 1				0.120	0.053	**
Land type 2				0.713	0.040	****
Land type 3				0.047	0.049	
Land type 4				0.009	0.045	
Land type 5				-0.016	0.041	
Fragmentation	0.536	0.207	**	0.084	0.142	
Age	-0.007	0.006		0.004	0.004	
Household language	0.213	0.228		0.451	0.152	***
% indigenous language	0.001	0.004		0.004	0.002	*
Expenditure	-0.0005	0.0002		-0.0002	0.0002	***
Family labor only	-0.156	0.177		-0.002	0.118	
Extension	0.392	0.238		-0.021	0.159	
Kilo por Kilo	0.059	0.197		0.071	0.130	
PROCAMPO	0.010	0.179		0.148	0.119	
Distance	0.000	0.003		0.000	0.002	
Inverse Mills Ratio	0.779	0.127	****	0.494	0.087	****
Constant	-0.532	0.561		-0.639	0.374	*
Log likelihood	-218.913			-148.94		
Log likelihood ratio test[1]	139.946 (4 df)****					

[1] Log likelihood ratio corresponding to a test that the two regressions are equal.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.

expenditure were also significant. Creolized varieties tend to be planted predominantly in *arado* lands irrespective of their perceived soil quality. Hence, creolized varieties tend to occupy a specific niche. Households that speak only Spanish tend to plant a larger area to these varieties, which is compatible with the hypothesis that creolized varieties are associated with an ability to interact better with the regional and national economies. Conversely, they are less acceptable to speakers of an indigenous tongue, which would suggest that they do not have the special cultural characteristics that these households demand. This point is contradicted, however, by the fact that households in communities with a higher percentage of indigenous speakers tend to plant more of them. This suggests that creolized varieties may not be inferior from a cultural point of view, but perhaps are more accessible to those who are able to interact with the regional and national economies. Finally, households with lower predicted expenditures tend to plant more of these varieties. This is compatible with our key hypothesis that the poor benefit from creolized varieties.

As for use of landraces, model B is statistically different from model A, indicating that land quality is a factor in adoption (Table 9). In fact, it is the only factor that explains landrace adoption. Landraces are planted in all land qualities, except for one—*arado* of intermediate quality. This is the land type where creolized varieties, in particular, are planted—though not exclusively. There seems to be a niche differentiation between creolized varieties and landraces. Also, landraces seem to have wide adaptation, while adaptation of creolized varieties may be narrower.

It is interesting to note that government programs do not seem to have any impact on the adoption of any of these maize types, and neither does distance. While formal links to the regional and national economies do not seem important, language is, so the more informal link seems to be more relevant. Adaptation, risk, and management intensity are the factors influencing the choice of maize germplasm in Oaxaca.

To explore whether these germplasm types complement or substitute each other, the disturbances associated with each regression were correlated. The correlation between the disturbances of improved varieties and creolized varieties was negative and highly significant (-.276, $p<.001$), indicating that these two types of germplasm are substitutes. The correlation between the disturbances of creolized varieties and landraces was negative, but only weakly significant (-.143, $p<.10$), which indicates that these two types of germplasm are very weak substitutes. The disturbances of improved varieties and landraces were not correlated.

Results from Chiapas

Results of the estimations for Chiapas are described below. For the adoption of hybrids, the results show that while land quality is not a factor in adoption, total landholdings are (Table 10). Farmers with larger landholdings tend to plant a larger area to hybrids. This result seems to contradict the hypothesis that hybrids have low adaptation and are only planted in certain lands. It should be pointed out, however, that these farmers apply very high rates of fertilizer to their fields (~200kg of N / ha), which tends to

Table 9. Regression results of two adoption models for landraces, Coast of Oaxaca

	Model A			Model B		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Total area	0.135	0.033	****			
Land type 1				0.505	0.056	****
Land type 2				0.004	0.043	
Land type 3				0.333	0.052	****
Land type 4				0.148	0.048	***
Land type 5				0.073	0.044	*
Fragmentation	-0.192	0.175		-0.200	0.152	
Age	0.005	0.005		0.002	0.004	
Household language	-0.008	0.192		-0.130	0.162	
% indigenous language	0.004	0.003		0.003	0.002	
Expenditure	0.0002	0.0002		0.00008	0.0002	
Family labor only	0.028	0.149		-0.089	0.125	
Extension	-0.113	0.201		0.004	0.170	
Kilo por Kilo	0.212	0.166		0.189	0.139	
PROCAMPO	0.058	0.151		0.057	0.126	
Distance	0.000	0.002		-0.002	0.002	
Inverse Mills Ratio	0.735	0.096	****	0.721	0.082	****
Constant	0.265	0.474		0.509	0.399	
Log likelihood	-191.359			-159.411		
Log likelihood ratio test[1]	63.896 (4 df)****					

[1] Log likelihood ratio corresponding to a test that the two regressions are equal.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.

Table 10. Regression results of two adoption models for hybrids, La Frailesca, Chiapas

	Model A			Model B		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Total area	0.486	0.051	****			
Land type 1				0.257	0.116	**
Land type 2				0.508	0.113	****
Land type 3				0.479	0.069	****
Land type 4				0.526	0.055	****
Land type 5				0.218	0.202	
Fragmentation	-0.725	0.213	****	-0.756	0.212	****
Age	-0.012	0.012		-0.008	0.012	
% indigenous language	-0.056	0.069		-0.101	0.073	
Expenditure	0.0005	0.001		0.0004	0.001	
Family labor only	0.208	0.342		0.143	0.344	
Extension	-0.028	0.441		0.034	0.442	
Kilo por Kilo	0.707	0.364	*	0.651	0.367	*
PROCAMPO	-0.378	0.444		-0.441	0.442	
Distance	-0.005	0.002	**	-0.005	0.002	**
Inverse Mills Ratio	1.776	0.231	****	1.776	0.229	****
Constant	0.856	0.828		0.931	0.823	
Log likelihood	-333.248			-329.412		
Log likelihood ratio test[1]	7.672 (4 df)					

[1] Log likelihood ratio corresponding to a test that the two regressions are equal.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.

homogenize the fertility conditions of the soil. Hence, the lack of significance of land quality may be related to the homogenizing effect of fertilizer use. Other statistically significant variables were fragmentation, participation in government programs distributing improved seed, and distance of the community from the main town.

The sign of fragmentation is compatible with the hypothesis that hybrids are management-intensive. Participants in the Kilo por Kilo program on average plant a larger area to hybrids than non-participants, which is consistent with the finding that this program has had a positive impact on the adoption of this germplasm type. As the distance of the community from a key nodal town increased, the area planted to hybrids decreased. It is important to point out that predicted expenditure and, hence, welfare was not significant. This contradicts the common argument that hybrids are less appropriate for the poor. If this hypothesis were correct, one would expect a negative and statistically significant relationship between this variable and the area planted to hybrids.

Results on the adoption of recycled hybrids and OPVs show that land quality is a significant factor influencing adoption (Table 11). These types of varieties in particular are planted on lands of intermediate quality regardless of the production system. The use of family labor was the only other significant factor. Households that rely exclusively on family labor tend to plant a smaller area to these varieties, which is compatible with the hypothesis that they are labor intensive.

As for the adoption of creolized varieties (Table 12), results show that model B is statistically different from model A, indicating that land quality does play a role in adoption of these varieties. These varieties are planted in either the best or the worst lands, suggesting that they may have wide local adaptation. Fragmentation, percentage of indigenous speakers in the community, use of family labor only, participation in government programs, and distance from a key town were also significant. The sign of fragmentation is consistent with the hypothesis that these varieties are widely adapted (consistent with the result that they are planted in the best and worst lands), not management-intensive and less risky, and, hence, better known. The fact that farmers who rely exclusively on family labor plant more creolized varieties is also consistent with the hypothesis that they are not management-intensive.

Farmers in communities with a larger presence of indigenous speakers tend to plant less area to these varieties, which suggests they may be inferior from a cultural point of view. Participants in both government programs plant on average a larger area to creolized varieties than non-participants, which is consistent with the hypothesis that these programs have had a positive impact on the adoption of this type of varieties. Contrary to the hypothesis, as the distance from a key nodal town increased, the area planted to creolized varieties increased as well. This contrasts with the results for hybrids and may indicate that, as time passes, farmer-to-farmer dissemination of these varieties takes place. Results suggest that

Table 11. Regression results of two adoption models for recycled hybrids and open-pollinated varieties, La Frailesca, Chiapas

	Model A			Model B		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Total area	0.080	0.049				
Land type 1				0.107	0.111	
Land type 2				0.310	0.108	***
Land type 3				-0.008	0.066	
Land type 4				0.093	0.052	*
Land type 5				0.226	0.193	
Fragmentation	-0.023	0.206		0.008	0.203	
Age	-0.010	0.011		-0.010	0.011	
% indigenous language	-0.093	0.067		-0.049	0.069	
Expenditure	-0.001	0.001		-0.001	0.001	
Family labor only	-0.630	0.332	*	-0.571	0.329	*
Extension	-0.328	0.427		-0.362	0.423	
Kilo por Kilo	-0.173	0.352		-0.367	0.352	
PROCAMPO	-0.266	0.430		-0.328	0.423	
Distance	0.002	0.002		0.002	0.002	
Inverse Mills Ratio	-0.822	0.224	****	-0.822	0.219	****
Constant	2.531	0.801	***	2.365	0.788	***
Log likelihood	-327.981			-322.456		
Log likelihood ratio test[1]	11.05 (4 df)	**				

[1] Log likelihood ratio corresponding to a test that the two regressions are equal.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.

Table 12. Regression results of two adoption models for creolized varieties, La Frailesca, Chiapas

	Model A			Model B		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Total area	0.032	0.028				
Land type 1				0.247	.062	****
Land type 2				-0.016	0.060	
Land type 3				-0.033	0.037	
Land type 4				0.025	0.029	
Land type 5				0.243	0.108	**
Fragmentation	0.358	0.119	***	0.403	0.113	****
Age	-0.005	0.007		-0.007	0.006	
% indigenous language	-0.112	0.039	***	-0.083	0.039	**
Expenditure	0.001	0.001		0.001	0.0005	
Family labor only	0.295	0.191		0.326	0.184	*
Extension	0.228	0.246		0.135	0.236	
Kilo por Kilo	0.326	0.203		0.354	0.196	*
PROCAMPO	0.370	0.248		0.421	0.236	*
Distance	0.002	0.001	*	0.003	0.001	**
Inverse Mills Ratio	2.075	0.116	****	2.075	0.110	****
Constant	-0.228	0.462		-0.312	0.440	
Log likelihood	-238.788			-227.910		
Log likelihood ratio test[1]	21.756 (4 df)****					

[1] Log likelihood ratio corresponding to a test that the two regressions are equal.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.

creolized varieties are versatile and fit well in more marginal conditions, but may still lack the cultural-based attributes that some farmers value.

Results for the adoption of landraces show that land quality was not a significant factor in adoption (Table 13). However, total landholdings were marginally significant, indicating that farmers with larger landholdings plant a larger area to landraces. Fragmentation, farmer's age, and percentage of indigenous speakers in the community were other statistically significant variables affecting adoption. The sign of fragmentation is consistent with the hypothesis that these varieties are well adapted, not management-intensive, less risky, and, hence, better known—similar to creolized varieties—as one would have expected. Older farmers tend to plant a larger area to these varieties than younger ones, which is consistent with the hypothesis that these varieties are less risky and better known by more experienced farmers. Finally, the fact that farmers in communities with a higher percentage of indigenous speakers plant a larger area to these varieties is consistent with the hypothesis that these varieties have the cultural attributes associated with a strong tradition of maize cultivation and consumption. Even in highly commercialized systems such as Chiapas, culture plays a key role in adoption decisions and seems to be the principal reason for maintaining landraces.

To determine whether these maize germplasm types are complements or substitutes, the disturbances associated with each regression were correlated.

Table 13. Regression results of two adoption models for landraces, La Frailesca, Chiapas

	Model A			Model B		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Total area	0.093	0.047	*			
Land type 1				0.041	0.110	
Land type 2				0.014	0.107	
Land type 3				0.102	0.065	
Land type 4				0.106	0.052	**
Land type 5				-0.050	0.191	
Fragmentation	0.524	0.198	***	0.512	0.201	**
Age	0.028	0.011	**	0.029	0.011	***
% indigenous language	0.383	0.064	****	0.354	0.069	****
Expenditure	-0.001	0.001		-0.001	0.001	
Family labor only	-0.173	0.318		-0.210	0.325	
Extension	0.520	0.410		0.542	0.418	
Kilo por Kilo	-0.364	0.338		-0.316	0.348	
PROCAMPO	0.165	0.413		0.174	0.418	
Distance	0.002	0.002		0.001	0.002	
Inverse Mills Ratio	1.683	0.229	****	1.683	0.230	****
Constant	-2.237	0.770	***	-2.172	0.778	***
Log likelihood	-321.479			-320.488		
Log likelihood ratio test[1]	1.982 (4 df)					

[1] Log likelihood ratio corresponding to a test that the two regressions are equal.
*, **, ***, ****, significant at the .10, .05, .01, .001 levels, respectively.

Correlations between the disturbances of hybrids and recycled hybrids and OPVs (-.234, p<.01), hybrids and creolized varieties (-.168, p<.05), and hybrids and landraces (-369, p<.01) were negative and significant, which indicates that hybrids are substitutes for the other germplasm types. There was also a negative and statistically significant correlation between landraces and creolized varieties (-.213, p<.01), indicating that these two germplasm types are substitutes. The disturbances of recycled hybrids and OPVs and creolized varieties were not correlated.

General results

In general land quality is an important factor in the adoption of most maize types in both Oaxaca and Chiapas, particularly for creolized varieties. Even if land quality *per se* is not important, the size of landholdings is, except for improved varieties in Oaxaca, which are planted in a very limited area. This indicates that adaptation is an important consideration for adoption. Fragmentation is another factor that was significant for most types of maize germplasm, indicating the importance of both adaptation and management intensity. Language and culture also play a role in adoption, particularly of creolized varieties and landraces in Chiapas. The use of family labor (and hired labor) is a factor in the adoption of certain maize germplasm types, but not in all, suggesting that certain types are considered more labor-intensive than others. Expenditure and, hence, welfare and poverty were not significant factors in the adoption of any maize germplasm type, except for creolized varieties in Oaxaca, where there was an inverse relationship between expenditure and adoption of creolized varieties; this indicates the poor tend to adopt these varieties. The lack of significance of expenditure suggests there is no direct relationship between the level of welfare of a household—at least in the narrow sense of expenditure—and its adoption decisions, except in the case already described.

Distance of the community from a main town was a factor that only influenced the adoption of certain germplasm types in Chiapas, but not in Oaxaca. Government programs do not play a significant role in adoption decisions in Oaxaca, but they do for certain germplasm types in Chiapas, particularly creolized varieties. They do not seem to have a direct negative impact on the use of landraces in either region. However, the different germplasm types seem to compete with each other in both study areas. As will be shown in the next section, this is not completely consistent with farmers' perceptions of traits and trade-offs, i.e., they believe one germplasm type may complement another by providing traits the other does not have.

Case Study Findings on Factors Influencing Adoption

The case study findings complement the results presented above by examining the reasons given by people for adoption or non-adoption. The most frequently cited factor that discourages adoption of improved varieties was cost. Interestingly, this reason was given only in Chiapas (though not very often by less-poor farmers); no one said this in Oaxaca. This can be explained by the fact that farmers in Chiapas are more commercially-oriented and use larger amounts of purchased inputs; furthermore, their maize grain has to comply with commercial standards. To compete on the market, they need to purchase improved seed, making price a consideration. Farmers in Oaxaca are mostly subsistence-oriented, use small amounts of purchased inputs, and make limited use of improved varieties. Curiously, a number of Oaxacan farmers said that price was not a factor, that they would find a way to buy improved seed if they thought it was good quality, but that observations and rumors of poor quality have convinced them that is not the case.

Other factors mentioned as discouraging adoption, though only by a few farmers, were that the seed did not arrive on time. Interestingly, the perception that "improved seed is for the rich" was only expressed by a handful of informants in each state. This does not support one of our initial hypotheses on why poor farmers do not adopt improved seed, although references to its high cost in Chiapas, and its relatively low adoption level by subsistence farmers in Oaxaca, would seem to implicitly support this hypothesis. However, it is consistent with regression results that show that expenditure (a welfare indicator) was not significant in most adoption decisions.

The factor most commonly cited in Oaxaca to explain non-adoption or adoption was that new seeds are risky: "Other varieties have come, trial plots have been planted, but they don't work out because people don't want to change their *criollo* seeds or because you can't always risk losing the year's harvest. You keep work and money in mind, and so you keep planting the *criollo* varieties." The issue of risk came up repeatedly throughout the study, particularly among poorer farmers. However, even a less-poor farmer said, "I already decided that right now only the pure *criollo* is the safest; that way there is no risk."

This concern over risk is one of the main reasons people decide to adopt or not to adopt, and they base the decision on the good or bad yields and other traits they observe in new maize varieties planted by family, friends, and neighbors. The issue of observing before doing came up repeatedly. Most case study informants in both Oaxaca and Chiapas said people prefer to observe how new seeds produce before trying them. People see the experimental plots planted by the Ministry of Agriculture and even when they look nice, some suspect the technicians might have added a secret ingredient and wonder if the varieties will yield as well on their land. When a new variety is introduced in Oaxaca, people test it in small areas before sowing whole fields with it. However, risk tolerance showed a clear pattern: the poorer the farmer, the less willing he is to risk his harvest. When asked if he would plant seed promoted by an outside organization, an average-poor farmer from Tiltepec said, "No. Even if they gave it to me for free, I would wait to see someone else's crop. Since I have my seeds, I will plant my own. Why should I try the new seed? All I would do is expose myself to losses."

Another set of factors explaining adoption relates to farmers' access to different types of capital. Financial capital is needed to purchase seeds (as described above) and also inputs such as fertilizer and pesticides. This is especially true in Chiapas, where improved varieties that require applying specific inputs to reach their full potential are more widely used. Social capital is also needed to obtain seed through informal social networks, *campesino* organizations, and political campaigns. Political capital, in the form of political contacts and party affiliation, is also helpful. Human capital—e.g., access to healthy laborers to work the land—helps as well. To make adoption worthwhile, natural capital—e.g., sufficient amounts of good quality land and the right soil type—also plays a role.

The relationship between soil type and maize varieties was important to case study informants. They had some idea of certain varieties matching certain soil types, but were not explicit in this regard. For example, in Oaxaca informants said "the land chooses the seed," as farmers learn "by trial and error." They also believe certain maize varieties do better on particular types of soils. A farmer in Tiltepec said that "Tepecente" maize is a "beggar" because you have to beg it to grow: if it doesn't like a field it produces poorly. However, no one in Oaxaca specifically mentioned soil type as a reason for deciding to plant a given variety.

In Chiapas, farmers were somewhat more explicit on the importance of soils. They believe using expensive improved seed is justified only if planting on good soils such as flat bottomland. On poor soils (over-farmed, steeply sloping land where proper fertilization is not possible because it washes away), it is best to plant *criollo* seeds. These expressed beliefs, however, contrast with the regression results for hybrids in Chiapas, where no land type effect on adoption was detected. Farmers said that *criollo* maize does well on any soil type, even worn-out and weed-covered land. This reflects the notion that *criollos* have become acclimatized to local soils. Some people believe that it is best to plant tall varieties on hillsides, where the worn-out land reduces plant height so that the wind will not affect them. In Dolores, farmers said that some *criollo* varieties (San Gregorio and Opalo) are for old fields that are tired and "advanced."

Finally, traits of the different varieties are an important set of factors that explain adoption. They were described in more detail through the survey data (see the following chapter on impacts). Case study informants said the traits they like most in the *criollos* are the appearance of the ears, large kernels, good flavor, and robustness. The principal disadvantage they find in *criollo* varieties is their great height, which causes the plants to topple over with the wind. Each variety is said to have different advantages; for example, Rocamey in Chiapas is said to yield well in any terrain, even weed-infested fields. It yields well year after year, produces sweet, tender ears, and rarely fails; furthermore, its grain does not shatter ("like seeds from the Ministry do") and is very resistant to grain borers. Farmers also appreciate the high grain weight, good yields, and lower height of improved varieties (though they also claim they are so short animals eat them), but they do not like the small ears, fragility, tendency to rot, and the kernels' tendency to shatter. Additionally, improved seeds are costly, require more care and greater investment of time and inputs, and yield less over the years. In both study areas there are stories of people being poisoned by applying an insecticide to improved maize to repel pests, because they did not read the instructions (many farmers do not speak or read Spanish). Finally, some farmers said that improved varieties taste bland. Below are some examples of farmers' perspectives.

Criollo seeds are more reliable. The only risk is that the plants grow tall. But if they have already ripened… and have ears that are starting to turn yellow, even if the wind blows them down, I haven't lost. The only thing I will lose is the time to go and prop them up with a forked stick…As for lodging resistance, [improved varieties are better] *in the sense that they are shorter and the winds pass over them…like Tuxpeño and Tacsa…which are special for the wind. But when we see the little ears they produce, we don't consider them reliable and we want larger ears. We are used to producing big ears, so that we can pick just a few to take home.* (Average-poor farmer, Dolores, Chiapas).

It would be better to buy [seed from] *a bag, since it yields better. The only problem is that it is too expensive. Another problem with seeds from a bag is that you have to plant them very close together, only one grain per hole. It takes more work, more pesticides, and more fertilizers.* (Less-poor farmer, Querétaro, Chiapas)

Chapter 6

Impacts

Impacts are analyzed in this chapter based on the principle that households derive utility from the crop's traits or attributes, rather than from the crop itself (see, for example, Adesina and Zinnah 1993; Barkley and Porter 1996; Edmeades et al. 2004; Hintze et al. 2003; Smale et al. 2001). Clearly changes in the supply of valued traits have important welfare implications for farmers, beyond trade-offs between the level of expected yields and the variance (or variability) in yield performance (Edmeades et al. 2004). As many studies have shown, small-scale farmers who plant maize for subsistence and, particularly, those who also sell some of their production value multiple traits in their crop. Usually no single variety can provide all the valued traits; hence, farmers continually face trade-offs in their variety choices (Bellon 1996; Smale et al. 2001). To the extent that these trade-offs are lessened, farmers benefit because they can satisfy their preferences at a lower cost.

A key hypothesis of this study is that farmers, particularly the poor, benefit from improved germplasm through creolization. While improved varieties provide desirable traits or trait combinations not found in landraces, they may lack traits landraces do have. Hence, choosing between them implies trade-offs to farmers. Creolized varieties can provide traits not supplied by landraces, and entail fewer trade-offs than improved varieties. Hence, to determine the impact of these varieties on farmers' well-being, one has to examine the importance farmers attach to each trait, as well as the supply of traits offered by different maize germplasm types.

The survey included a section on farmers' evaluation of maize varieties. They evaluated 19 crop traits identified as significant in focus group discussions. In the first part of the evaluation, farmers assessed the importance they give to different crop traits. Men and women farmers rated each trait as very important, important, or not important in terms of its relevance for choosing a maize variety to grow. In the second part farmers evaluated the extent to which each germplasm type supplies the traits they value. Men and women rated each variety's performance for each of the 19 traits as very good, good, poor, or very poor. Sometimes farmers did not rate a currently grown variety because they did not feel they knew enough about their performance. Later we grouped variety ratings by maize types according to the definitions presented in the section on maize germplasm (p. 16).

Importance of Crop Traits for Farmers

Although numerous traits were evaluated, almost all farmers in both Oaxaca and Chiapas rated them as either very important or important. Table 14 presents the percentage of farmers, by gender, who rated each trait as very important in both study areas. Almost all traits were rated as very important by 50% or more of farmers in both study areas. This suggests that focus groups were very accurate at identifying relevant crop traits, and that farmers value multiple traits. To determine whether any of the traits were particularly important to the poor, non-parametric correlations between household expenditure and importance ratings were run for each trait. A significant negative correlation indicated that as expenditure decreases, importance increases and, hence, the trait is more important to the poor. Table 14 shows statistically significant correlations as well.

Traits rated as very important by the highest number of male farmers in Oaxaca are yield by weight, tortilla dough yield, ease of shelling, and lodging resistance. Yield by weight is a key trait for breeding. Tortilla dough yield is seldom taken into account by breeders. Lodging is a key source of risk and vulnerability in maize production. As pointed out earlier, farmers in Oaxaca are still heavily oriented towards subsistence

Table 14. Percentage of farmers who rated a trait as very important in Oaxaca and Chiapas, Mexico, by gender

	Coast of Oaxaca				La Frailesca, Chiapas			
	Men	Correl.[1]	Women	Correl.[1]	Men	Correl.[1]	Women	Correl.[1]
Number of households	162		162		161		158	
Vulnerability								
Lodging resistance	69.8		98.8		82.6		94.3	–.120*
Drought tolerance	75.9		83.3	–.117*	75.2		72.2	
Tolerance to excess rainfall	54.3		84.6		70.8		88.6	
Ear rot resistance	61.1		75.2	–.162**	68.9		80.4	
Length of growing cycle	49.4	.169**	80.9		62.1		82.3	
Field pest resistance	66		83.3	–.145**	69.6		80.4	
Storage pest resistance	58.6		75.9		61.5		80.5	
Produces even in a bad season (yield reliability)	58		75.9		64.6		76.7	
Good for sale	55.9	.181**	65.4		63.8		81.8	
Consumption-related								
Good for consumption	59.9		80.2		70.2		84.9	
Good for *atole*	59.3		91.4		68.9		90.6	
Good *elotes* for sale and consumption	50.6	.118**	69.8		60.2		74.2	
Good for *antojitos* (special maize preparations)	58.6		75.9		65.2		79.2	
Ease of shelling	70.4		76.5		42.9		73	
Good for *nixtamal*	61.1		84.6		68.9		83.6	
Good for fodder	27.8	.155**	54.8		49.1	–.122*	64.8	
Productivity								
Yield of tortilla dough	77.2		92		83.9		89.2	
Yield by weight	84.6		67.9		89.4		67.1	
Yield by volume	67.9	.120**	61.1		72.7		68.4	

[1] Non-parametric correlation between predicted expenditure and importance rating. A negative sign indicates importance increases with poverty, and vice versa.
*, **, correlation significant at the .10 and .05 levels, respectively.

farming, so tortilla dough yield and ease of shelling are understandably high priority traits. Correlations indicated that as poverty decreases, length of growing cycle, good for *elotes* (corn on the cob), and good for fodder become more important. There were no traits that seem to be particularly important to poor male farmers. Traits rated highest by women farmers were lodging resistance, tortilla dough yield, *atole* quality, tolerance to excess rainfall, and *nixtamal*[26] quality. Consumption characteristics are clearly more relevant to women than to men, as would be expected, since women are in charge of maize processing and preparation. The data indicated that women also attach a great deal of importance to reduced vulnerability. Correlations showed that three traits are significantly more important to poor women farmers: drought tolerance, ear rot susceptibility, and pest resistance. These traits are clearly related to vulnerability factors, which appear to be more important to women than to men.

Traits rated as very important by the highest number of male farmers in Chiapas were very similar to those for men in Oaxaca: yield by weight, yield of tortilla dough, lodging resistance, drought tolerance, and yield by volume. Only the importance rating of one trait is associated with the poor: good for fodder. Traits rated as very important by the highest number of women in Chiapas were similar to those indicated by women in Oaxaca. There is a consistent pattern of consumption characteristics being more relevant to women than to men. This shows that despite the high level of commercialization, and although marketability is considered more important than in Oaxaca, subsistence production is still relevant to women in Chiapas. Only the importance of resistance to lodging, a vulnerability factor, is associated with the poor.

Supply of Traits

To systematically examine farmers' perceptions of the performance of the varieties available with respect to the characteristics they value, proportional odds regressions (Agresti 1996; Coe 2002) were run for all 19 traits identified in Table 14. The proportional odds model relates a dependent variable consisting of ordered response categories (e.g., farmers' ratings of performance for a trait) to a set of independent variables (e.g., maize germplasm types grown by farmers, as defined on p. 16, and other covariates explained below). The model was estimated independently for the 19 identified traits, separately for men and women, and individually for the two study areas. The results of this type of regression in this context are the ratio of the odds that farmers rated a maize category as superior compared to another maize category for a particular trait. Included in the regression was the predicted expenditure, used in the chapter on adoption as a covariate to correct for differences in ratings associated with different welfare levels.

Because women may not have participated directly in growing many varieties and, hence, may have had very limited knowledge and experience of the variety, which could bias their ratings, a dummy variable

26 *Nixtamal* is the local word for maize grains that have been boiled as the first step towards making tortillas. Tortilla dough is produced by grinding the *nixtamal*. During the survey, we used *nixtamal* when referring to dough quality and yield of tortilla dough (or dough yield) when referring to the rate of transformation between the amount of grain in the *nixtamal* and the number of tortillas produced from it.

specifying whether they had actually participated in growing the variety or not was also included in the regressions of female ratings (results for Oaxaca and Chiapas presented in Tables 14 and 15, respectively). For simplicity these tables only present traits that showed statistically significant differences. The tables should be interpreted as follows: the category presented in the row was rated as superior to the category in the column for the traits described in the cell where they intersect. For example, in Table 15, for male farmers, creolized varieties were rated as superior to landraces for yield by weight and lodging resistance, while landraces were rated superior to creolized varieties for ease of shelling, good for *nixtamal*, good for *elotes* and good for fodder. By comparing the traits described in cells that result from inverting the categories in the rows and the columns, one can identify the trade-offs between two types of maize categories. For example, in Table 15, for male farmers, the trade-offs between landraces and improved varieties are ear rot resistance and ease of shelling, versus lodging resistance.

Results from Oaxaca

Table 15 shows there were statistically significant differences for 7 of the 19 traits rated by men in Oaxaca. There was no overall superior maize type; all types have advantages and disadvantages. Most advantages were associated with landraces; however, both improved and creolized varieties were superior with respect to lodging resistance, a key vulnerability factor in the area. While landraces are considered superior for many traits, improved varieties and creolized provide a trait they lack: lodging resistance. Furthermore, creolized varieties, although inferior to landraces for some consumption traits (good for *elotes*, *nixtamal*, and fodder, and ease of shelling), were superior for yield by weight. Clearly these maize types show some trade-offs between key traits. These results support our hypothesis that creolized varieties provide a combination of traits not provided by landraces or improved varieties, and hence entail fewer trade-offs.

Table 15. Comparisons of different types of germplasm with respect to traits with statistically significant differences in ratings, Coast of Oaxaca, by gender (female ratings preceded by an F)

Categories in rows rated superior to categories in columns	Improved varieties[a]	Creolized varieties	Landraces
Improved varieties		• F- produces even in bad season *	• lodging resistance** • F-lodging resistance**
Creolized varieties			• lodging resistant*** • yield by weight*** • F- lodging resistant***
Landraces	• ear rot resistance** • ease of shelling*** • F-ease of shelling*	• ease of shelling**** • good for *nixtamal**** • good for fodder* • good *elotes**	

[a] Improved varieties include hybrids, recycled hybrids, and OPVs, which were added together due to the low number of observations by category.
*, **, ***, **** statistically significant at the .10, .05, .01, and .001 levels. The significance level was adjusted by the number of pair-wise comparisons.

Furthermore, creolized seed is much less costly. For example, hybrid seed costs, on average, MX$17.44 / kg, compared to MX$5.33 / kg for seed of creolized varieties, while seed of landraces costs MX$3.88 / kg. This is in agreement with results of the qualitative study where farmers said though seed of improved varieties was very expensive, they would "sacrifice" and buy it if improved varieties were truly superior, which they did not consider to be the case. The price differentials between seed of creolized varieties and landraces also illustrate that farmers perceive advantages in the former compared to the latter, since they are willing to pay a premium.

For women, there were statistically significant differences for only three of the rated traits. For two of these traits, lodging resistance and ease of shelling, the results are similar to those of men. Only for yield reliability (i.e., yields even in a bad year) women rated improved varieties higher than creolized varieties, unlike men, for whom there were no differences. One would have expected creolized varieties to be rated higher in this respect given they have been grown longer in these areas and thus could be better adapted and more stable (low year-to-year variability). There is no clear explanation for these results, which merit further investigation.

As indicated in the chapter on methods, a dummy was included in the female regressions to account for the actual experience of growing a variety. This variable was statistically significant for several traits[27] indicating—not surprisingly—that women' actual experience with varieties influences their perceptions of varietal performance.

Results from Chiapas

Table 16 shows that for men in Chiapas, there were statistically significant differences for 9 of the 19 traits rated. There is no type that is superior for all traits, as in the case of Oaxaca. However, unlike the situation in that state, in Chiapas there is a wider range of maize types, and thus more comparisons were made. In general, men have a very positive opinion of hybrids. They rated hybrids higher than OPVs (in particular) and recycled hybrids for several traits related to consumption and marketing characteristics. However, OPVs, creolized varieties, and landraces were rated higher than hybrids when it came to storage pest resistance, a key trait for subsistence farmers. Landraces were also rated higher than hybrids with respect to ear rot resistance. Storage pest resistance and ear rot resistance are closely linked to vulnerability, suggesting that landraces are valuable for addressing vulnerability issues. Overall, improved varieties were rated superior to landraces for lodging resistance.

Farmers' ratings of creolized varieties do not indicate they perceive these varieties to have many or unique advantages, unlike in Oaxaca. However, the price of creolized seed is on average higher than that of landraces (MX$ 6.33 / kg vs. MX$ 3.51 / kg, respectively) and much lower than the hybrid price (MX$ 20.25 / kg), suggesting farmers are willing to pay a premium for creolized varieties over landraces.

[27] Traits for Oaxaca included lodging resistance, field pest resistance, good for *nixtamal*, storage pest resistance, and yield of tortilla dough.

For women there were statistically significant differences for only four of the traits rated. Women perceived hybrids to be inferior to landraces, creolized varieties, and even recycled hybrids. They perceived more and unique advantages in creolized varieties and landraces. Recycled hybrids were rated high for yield reliability compared to other types of improved germplasm. As in the case of Oaxaca, however, there were many traits for which the variable indicating actual experience with a type of germplasm was significant, i.e., that women's actual experience with varieties influences their perceptions and how they rate traits.[28]

In summary, neither in Oaxaca nor in Chiapas is there an overall superior maize type; all types have advantages and disadvantages. In the subsistence-oriented farming systems of Oaxaca, landraces seem to be more advantageous, while in the commercially oriented systems of Chiapas, hybrids seem to have more advantages. Creolized varieties, while commonly planted by all poverty groups in both regions, are perceived more advantageously in Oaxaca than in Chiapas, even though in the latter women do have more positive perceptions of creolized varieties compared to hybrids.

Case Study Perspectives on Impacts on Poverty and Well-Being

The case studies reveal a number of ways in which creolized maize contributes to the well-being of poor farmers in the study areas. Unlike the survey results, the case

Table 16. Comparisons of different germplasm types with respect to traits with statistically significant differences in ratings, La Frailesca, Chiapas, by gender (female ratings preceded by an "F")

Categories in rows rated as superior to categories in columns	Hybrids	Recycled hybrids	OPVs	Creolized varieties	Landraces
Hybrids		• good for *elotes*** • good for *antojitos***^ • good for sale*	• good for sale*** • good for *antojitos*** • good for *atole** • good for *elotes** • good for fodder*	• lodging resistant* • good for *elotes**	• lodging resistant **** • good for sale***
Recycled hybrids	• F-produces even in bad season*		• F-produces even in bad season*		• lodging resistant***
OPVs	• storage pest resistance***				• lodging resistant*
Creolized varieties	• storage pest resistance**** • F-storage pest resistance* • F-field pest resistant*				
Landraces	• ear rot resistance*** • storage pest resistance*** • F-tolerant to excess rainfall*** • F-ear rot resistance*				

*, **, ***, ****, statistically significant at the .10, .05, .01, and .001 levels, respectively. The significance level was adjusted by the number of pair-wise comparisons.

[28] Traits for Chiapas included lodging resistance, field pest resistance, ease of shelling, storage pest resistance, yield reliability, yield of tortilla dough, and yield by volume.

studies did not elicit as many accounts of direct benefits from improved maize "from a bag," though certainly commercial production using improved maize was observed among farmers in Chiapas. The scarcity of positive feedback may reflect the fact that even where improved maize was providing important economic benefits, there were still problems, and people tend to express these when given a chance to talk about their experience. Nevertheless, the benefits of creolized maize, where improved maize has changed over time, emerged strongly in both Oaxaca and Chiapas, and across all three economic strata (less-poor, average-poor, and extreme-poor).

Creolized maize improves farmers' well-being mainly by reducing vulnerability. Poor farmers in both study areas depend on maize for their survival. Thus, by introducing germplasm that improves yields and reduces vulnerability to crop losses, vulnerability to food insecurity is also reduced. As an extreme-poor farmer in Nopala, Oaxaca, said, "…it is the food of our families; since we are all poor, we have no money to buy maize. If we don't plant it, what will we eat? Can you imagine?" Another extreme-poor farmer in Dolores, Chiapas, commented, "We have to take out the portion that is our food because there is no work; if we don't plant, we will starve."

By reducing what farmers spend on inputs and the cost of the seed itself, creolization frees up cash for other basic household expenses and reduces vulnerability to price and currency fluctuations. Farmers expressed that creolized seed combines the benefits of resistance and acclimatization to local conditions, with traits of improved seeds such as yield, height, and wind resistance. The case studies support the survey findings that creolized varieties provide the traits people prefer and reduce trade-offs.

It is also worth noting that, in association with the perception of recycling and acclimatization, farmers have a sense of security because they "know" the seed, which was repeatedly expressed as being particularly important. Farmers need to see seed perform before trying it, even if it means using second-generation seed. The fact that creolized varieties are trusted contributes to farmers' well-being in a subjective, but not less real, way by giving them a sense of security so that they worry less. This is particularly important for the poor and vulnerable.

The introduction of new germplasm has improved people's well-being, as confirmed by quote from a farmer in Nopala: "It has given us results. Since we bought that seed, many things began to improve for us: before, we had to buy lots of maize…but now we buy less. Last year I even sold some maize. This year we harvested less, but in September we will have the new maize." Still, adopting different varieties does not seem to significantly change people's livelihood strategies, which are actually driven by the risks involved in maize cultivation of any kind. Poor people in the two study areas cannot cover their basic necessities (for which they depend more and more on cash earnings) with the income (if any) they earn from growing maize. To grow maize, investments need to be made beforehand, which for most poor and average-poor farmers is not possible. For this reason, farmers said they cannot depend on maize cultivation for their livelihoods and emphasized difficulties related to cultivation. In summary, the more options people have to earn higher and more stable income, the less maize they plant.

One average-poor farmer from Querétaro, Chiapas, said he does not plant all of his land because it is expensive, risky, and uncertain, and he prefers other types of work. Likewise, one of the less-poor farmers in Querétaro who has 30 hectares of arable land planted only four hectares to maize and said he does better by raising cattle, trading, or renting out part of his land than risking everything on maize. If he loses the crop or has to sell the maize at low prices, he will not be able to recover his costs or earn acceptable returns. All of the informants in both regions said farming is risky, regardless of what kind of seed is used. When asked whether the new seeds have helped people to get ahead, an extreme-poor farmer from Dolores answered, "Look, no one—and I mean no one—can get rich growing maize around here...What with the cost of fertilizers and pesticides, the time we spend planting and processing, plus transportation…if you do the numbers, you realize you don't get anything back. Maize produces, but very little is left over. We are happy if we manage to grow enough to eat."

The question of whether particular maize varieties have contributed to alleviate poverty was not easily answered by farmers. They recognize the advantages of different types of seed, but since maize farming is not a profit-making activity, and because of the risks mentioned above, it was difficult for them talk about maize as a way out of poverty. In a curious paradox, maize cultivation is also described as a sign of vulnerability: "Planting maize means not having security; you plant because you have to, because maize is the basis of our diet. But you always need to have faith in God that there will be a good harvest. Because you can't control that. When you plant maize, you take a chance, even though you might have positive references about the seed." Even the better-off farmers (who nonetheless were at an intermediate level of marginality) in our case studies struggled with maize production:

> *I don't think it's possible to make a comfortable living from farming nowadays, with so much contamination, soil erosion from burning, etc. I don't think anybody can get ahead even if he has good hybrids, good* criollos. *It's just enough to get by. Everybody knows it's not profitable. Even if you make all of the necessary investments, in the end you just break even….however much a person harvests, he has already spent an equal amount on fertilizers, seeds, labor... Looking at the numbers, you just break even."* (Average-poor farmer, Dolores, Chiapas)

Despite these problems and the limitations of maize production as a way out of poverty, our study reveals that maize continues to be essential to people's welfare, for it guarantees food security and provides cash income for other basic needs. As one farmer said, "We need maize to live; without it we don't eat." For less-poor farmers engaged in commercial production, improved maize could make the difference between just getting by and prosperity. For both poor and less-poor farmers, there is no question that providing maize germplasm (through scientific breeding and creolization) that increases yields and reduces risks will make a significant difference in people's well-being. It may not enable them to escape from poverty, but then, that would require a more comprehensive poverty-reduction strategy reaching beyond agricultural technology.

CHAPTER 7

Conclusions

The coast of Oaxaca and La Frailesca, Chiapas, are highly contrasting regions. Poverty is endemic, even in the more commercialized and developed Chiapas. Maize continues to play a key role in the livelihoods of the poor in both regions.

This study has shown that modern varieties, and particularly creolized varieties, are widely planted in the study areas in Oaxaca and Chiapas. We cannot establish a direction of causality between the adoption of improved germplasm and poverty alleviation (i.e., by determining whether those who adopted improved varieties are better off in terms of income, expenditure, or nutritional status, because they did so, than those who did not), since we do not have a baseline study to compare the situation before and after adoption. Nonetheless, we have shown that improved germplasm and, particularly, creolized varieties contribute to the well-being of poor farmers by examining how these germplasm types supply—at least in farmers' perceptions—valued traits or trait combinations.

In Oaxaca, creolized varieties are perceived to provide traits that landraces lack and to entail fewer trade-offs than improved varieties. Seed of creolized varieties is also cheaper, and adoption patterns show that poor farmers plant them. In Chiapas, hybrids and other improved varieties seem to be neutral, i.e., poor farmers plant as much hybrid seed as the other farmers, once one corrects for other factors. The impact of creolized varieties is less straightforward in Chiapas than in Oaxaca, but they are still widely planted. This suggests that in more commercial systems where a wider range of germplasm types is planted, creolized varieties are not considered to be as advantageous (although this varies by gender), which contrasts with the situation in more isolated and subsistence-oriented systems. Linguistic and cultural factors, and agroecological factors to a much lesser extent, seem to play a key role in decisions to adopt different types of maize in both study areas. The evidence supports our hypothesis about creolized varieties and their role in farmers' maize production in Oaxaca, but this is much less clear in the case of Chiapas. Creolized varieties seem to occupy a niche that shifts according to the availability of improved germplasm and the orientation of farmers' maize production. One could say that creolized varieties are probably "second best" compared to other improved germplasm, but they seem to be the ones available to poor subsistence farmers in more isolated areas.

Although farmers discussed varieties and their traits, farmers' distinctions between creolized seed and landraces were blurred:

all seed that is not "from a bag" (improved varieties in a sealed package) is widely referred to as *criollo*. Furthermore, improved varieties are said to be quickly creolized through seed recycling, during which seed "acclimatizes" to the land and therefore improves. Even where seed is perceived to degenerate through recycling, it is still commonly practiced, given the high cost of new seed. Farmers perceive that creolization also occurs when they plant different varieties near one another so that they cross. They do this with different levels of intention. Some farmers deliberately plant varieties close together in the hope of incorporating better traits in the new variety. Regardless of the creolization method, farmers have a high level of confidence in creolized varieties, because they have been proven over time and are better adapted to local conditions.

Besides seed selected from their own harvest, farmers obtain seeds mainly through informal social networks and, to a lesser extent, government programs. Surprisingly, commercial seed outlets still play a very limited role. Social networks are key because they offer many options, are trusted and, most importantly, give farmers the opportunity to observe a variety in the field before adopting it. The need to see a variety's performance in the field (which reduces risk) is common to all farmers, but particularly the poorest. Maize is seen as a highly precarious enterprise, involving numerous risk factors. For this reason, known varieties that reduce these risks are important especially to the poorest, most vulnerable farmers.

Government programs play a more important role in Chiapas than in Oaxaca, but they suffer from a lack of credibility in both study areas. According to farmers, the programs have been plagued by problems such as seed arriving late, restricted access to credit, no technical support, politicization of seed distribution, and quantity and quality requirements that the poorest farmers cannot meet. Experience with poor quality seed has left farmers suspicious of government seed and improved seed in general. Also, they often do not trust the recommended management practices or cannot afford to follow them.

This research illustrated the value of combining different methodologies and approaches. The combination strengthened the evidence presented and facilitated interpreting the results, given that complementary insights were gained and similar conclusions were reached by applying different methodologies to the same issues. The sustainable livelihoods framework was useful for this research because it brought in issues not usually addressed in impact studies, such as vulnerability, understanding the role of maize in a wider context of farmers' knowledge and lives, and the processes and institutions that shape the impacts of technology, e.g., farmers' local networks and the interaction between farmers and government programs. These programs were not assumed to be inherently good or positive: though their strengths were recognized, their limitations and constraints, particularly from the farmers' perspective, were also taken into consideration.

Several implications can be drawn from these results.

- First, it is important to get away from the dichotomy of traditional versus modern varieties that is common in adoption and impact studies. As shown here, there are many different types of germplasm, each with its own advantages and disadvantages. All are influenced by different factors and have varying impact on farmers' well-being, depending on how well they provide valued traits that satisfy farmers' needs and preferences. It should be recognized, however, that moving away from this simple dichotomy presents methodological challenges that may require the use of multiple methodologies, including some that are not commonly applied in adoption and impact studies, such as participatory and ethnographic methods and collecting maize samples from farmers.
- A second implication, closely related to the above, is that we need to question the conventional adoption model for improved germplasm. This model assumes that the breeding process finishes once farmers have adopted a variety, and that a variety, once adopted, stays unchanged. And if the variety does change, the changes are likely to be negative. The seed should therefore be replaced either with new seed of the original variety or another that is even "better." The truth is, improved varieties do change in farmers' hands, but the changes are not necessarily negative; in fact, farmers often find them positive because they are associated with their selection and seed management practices. Rather than ignoring this process, we should try to find ways of taking advantage of it.
- This leads to a third implication, which is that, rather than provide poor farmers with finished OPVs or hybrids, the research system instead should offer them segregating materials with desirable traits that could be further selected to fulfill farmers' preferences. This should be done in conjunction with farmer training to make their selection more efficient (e.g., by teaching them to select not only for ear traits, as they currently do, but also relevant plant traits; see below).

This is an area that merits further research. As an example, CIMMYT is exploring a method called "targeted allele introgression," which allows the incorporation of valuable traits (such as drought tolerance and storage pest resistance) from elite germplasm into local maize populations and builds on farmers' seed management practices (Bergvinson and Garcia-Lara 2004). Further work in this area of research is required to address the needs and conditions of the poor, given that seed management practices, in general, and creolization, in particular, are more important to poor farmers, especially in subsistence-oriented systems. It should be noted, however, that creolization may only be valid for open-pollinated crops[29] and is perhaps not applicable to self-pollinated crops, such as wheat or rice, and certainly not to clonally propagated crops such as potatoes. This clearly limits the applicability of these results to other crops.

[29] In open pollination, plants are usually fertilized by pollen from other plants; in self-pollination, pollen from the same plant does the fertilizing.

- There is a need for scientists of different disciplines to jointly analyze what these results imply for the breeding and dissemination of improved germplasm. Clearly, this is something that social scientists cannot do alone. Breeders need to apply their technical expertise to judge the methods, feasibility, benefits, and costs of linking creolization to the breeding process.
- There is a need to go beyond a simplistic concept of yield as the yardstick of impact and look at the set of traits that farmers' value, how those traits are supplied by the available germplasm, and the trade-offs they entail. Decreasing these trade-offs has an important positive impact on farmers' well-being. That is the particular value of creolized varieties in the systems studied. Even yield is a more complex concept than the tons produced per hectare. As shown here, farmers have different concepts of yield that are not necessarily correlated, e.g., yield by weight, yield by volume, and yield of tortilla dough.
- Extension strategies should pay more attention to understanding local innovation and adaptation of improved varieties. Extension agents should not automatically assume that an "improved" variety is superior, especially for all traits that matter to farmers. An improved variety may indeed be superior for some traits, but not for others; hence the value of local adaptation and creolization. There may be a role for extension in strengthening the capacity of farmers to innovate and adapt improved varieties to their needs and circumstances, not just promoting adoption. For example, extension could teach farmers to understand maize reproduction better, thereby increasing their ability to creolize improved varieties.
- Researchers and extension agents should be aware of the actual practices farmers use when managing and recycling improved and creolized seeds, which will depend on their resource base, local beliefs, and access to and trust in different information sources. This would allow them to understand the usefulness of different varieties under different conditions, and the likely outcome of varietal introduction, adoption, and creolization.
- Poverty implications to farmers, the traits they need, and the constraints they face are not the same in subsistence- and commercially-oriented systems. For example, improved germplasm, particularly hybrids, benefit the poor more in a commercially-oriented system, and have much less value in subsistence or isolated systems. An *a priori* classification of areas based on the main focus of maize production should be very useful for targeting agricultural research to address the needs of the poor.

The implications of creolization for an agricultural research organization may be different depending on whether it is a center with a global mandate such as CIMMYT or a national research institute such as INIFAP in Mexico. For CIMMYT it may be important to determine the extent to which this process is used and appreciated in other maize regions of the developing world. For example, it is estimated that about 60% of the maize area in Latin America and 64% of the area in sub-Saharan Africa is planted to farmer-saved seed (Morris 2002), which suggests that creolization may also be important there. Creolization may be worth studying to understand the potential impact of transgenic maize varieties among the poor in areas where farmers recycle seed (see Bellon and Berthaud 2005).

It should be within the purview of CIMMYT to explore and develop innovative methods to improve the creolization process for the benefit of poor farmers, as discussed above (e.g., via targeted allele introgression). Clearly CIMMYT cannot and should not do this alone, but rather in close partnership with national programs that aim to impact the livelihoods of poor maize farmers who practice creolization. Perhaps the role of INIFAP should be to assess how important and widespread creolization is among small-scale Mexican farmers. If creolization is as important for the poor as our research suggests, then new methodologies that improve its efficiency in delivering germplasm relevant to the poor should be developed and implemented.

Finally, results suggest that tools used by poverty alleviation programs are useful for broadly targeting agricultural research. By focusing our research efforts on areas of high and very high marginality, we can begin addressing needs and issues relevant to the poor. Once the targeted regions have been identified, it is important to understand people's asset base, perceived risks, beliefs and experiences, social networks, and local political economy—and the relationships among them—to understand likely adoption and impact patterns. This can best be accomplished through a combination of conventional surveys and participatory and ethnographic methods. Our research has shown this can be achieved within a reasonable time period, using relatively low resources, and is worth the effort if helping poor farmers is a central objective.

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Appendix 1

The proportional odds model (based on Agresti 1996: 211-213)

The proportional odds model is based on the cumulative probabilities that a response variable Y falls in category *j* or below, for each possible *j*; *j* refers to ordered categories. The cumulative probabilities reflect the ordering $P(Y \leq 1) \leq P(Y \leq 2) \leq P(Y \leq 3) \leq \ldots \leq P(Y \leq J) = 1$. The logits for the first J – 1 cumulative probabilities are

$$\text{Logit}\,[P(Y \leq j)] = \text{Log}\left(\frac{P(Y \leq J)}{1 - P(Y \leq J)}\right)$$

The proportional odds model models the response of the cumulative logits associated with J response categories as a linear function of a set of predictors (X_i)

$$\text{Logit}\,[P(Y \leq j)] = \_i + \_x_i,$$

$$j = 1, \ldots, J\text{-}1;\ i = 1, \ldots, I$$

where J refers to the number of ordered response categories and I to the number of predictors. Predictors can be continuous, categorical, or both.

In our case, the response variable is the ratings (very good, good, poor, or very poor) farmers gave the varieties they plant based on their perception of the varieties' performance for traits identified as relevant. The predictors are the germplasm types associated with the ratings and predicted expenditure as a covariate. In the case of female ratings, an additional covariate was included to account for their actual experience growing the variety. Each coefficient reported in Tables 4 and 5 is the ratio between the odds that one germplasm type (e.g., hybrids) is rated higher with respect to a trait (e.g., lodging resistance) and the same odds for a different germplasm type (e.g., landraces). Each coefficient corresponds to a pair-wise comparison between two germplasm types; hence the significance level associated with each coefficient was adjusted by the number of pair-wise comparisons.

APPENDIX 2

Regression results for household expenditures by region[1]

	Oaxaca			Chiapas		
	Estimated coefficient	Standard error		Estimated coefficient	Standard error	
Constant	5.585	0.478	****	5.844	0.399	****
Age of male head (years)	-0.005	0.004		0.007	0.004	**
Education of male head (years)	-0.009	0.017		0.022	0.015	
Mother tongue of the head male (Spanish = 1, 0 = other)	0.335	0.108	****	-0.353	0.241	
Age of female head (years)	0.011	0.004	**	-0.005	0.004	
Education of female head (years)	0.039	0.023	*	-0.009	0.009	
Mother tongue of the head female (Spanish = 1, 0 = other)	-0.069	0.106		0.503	0.188	***
Household size (in adult equivalents)	-0.089	0.016	****	-0.130	0.018	****
Agricultural land holdings (ha)	-0.015	0.007	**	0.015	0.006	***
Index of animal holdings (1 = cow)	0.005	0.002	**	0.001	0.002	
Off-farm labor (1 = performs it, 0 = other)[2]	-0.109	0.078		-0.148	0.076	*
Non-farm farm labor (1 = performs it, 0 = other)[2]	0.160	0.100		0.130	0.096	
Temporal migration (1 = performs it, 0 = other)[2]	0.149	0.103		0.025	0.112	
Remittances (1 = receives them, 0 = other)[2]	0.027	0.119		0.176	0.112	
Owns house (1 = yes, 0 = no)	-0.572	0.331	*	0.025	0.182	
Access to safe drinking water (1 = yes, 0 = no)	-0.202	0.091	**	-0.152	0.197	
Access to sewage (1 = yes, 0 = no)	0.099	0.155		0.163	0.092	*
Earthen floor in house (1 = yes, 0 = no)	0.219	0.076	***	0.274	0.094	***
Access to health system (1 = yes, 0 = no)	0.628	0.180	****	0.043	0.089	
Number of people per room	0.079	0.035	**	0.082	0.049	*
Extraordinary expenses (1 = yes, 0 = other)[3]	1.807	0.246	****	1.293	0.472	***
Sample size	163			162		
R^3	.60			.52		
F-statistic	10.68			7.57		

[1] Dependent variable: log of the expenditures per household in adult equivalents.
[2] Performed over the previous five years.
[3] Refers to households that had extraordinary expenses such as building a house or high medical bills.
*, **, ***, **** significant at the .10, .05, .01, .001 levels, respectively.