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Preface and acknowledgements

A livelihoods approach to impact assessment captures a wider range of factors that affect farmers' welfare than those captured by conventional impact assessment. CIMMYT recently completed two innovative studies that took a livelihoods approach to assessing in more comprehensive ways the impacts of maize research projects in Mexico and Nepal. In Mexico, CIMMYT collaborated with the *Instituto Nacional de Investigaciones Forestales, Agricolas, y Pecuarias* (INIFAP), and in Nepal with the National Agricultural Research Council (NARC).

This paper compares and contrasts the two studies. We distill the key impacts of research, the International Public Goods, and the lessons learned, so as to better target and enhance maize research to improve the livelihoods of farmers in the future. In the Oaxaca study in Mexico two new tools for socio-economic research were tested and piloted: Personal Digital Assistants (PDAs) to collect real-time field data from farmers, and Google Earth™ to organize and analyze spatial data. The two studies integrate livelihoods and economic analyses to assess impact. Also based on the experiences in these studies, CIMMYT published *Guidelines for assessing impacts of agricultural research on livelihoods* in 2007. The Oaxaca study was described in *Livelihood approaches in multi-dimensional impact assessment,* a chapter in *Strategic guidance for impact assessment of agricultural research* by the CGIAR Standing Panel on Impact Assessment, 2008.

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Executive summary

To fully assess the impact of new technologies on farmers we need to shift the focus of research from 'crops' or 'commodities' to the impact pathway which links improved crop germplasm and management to household well-being. Household well-being includes factors such as food security, more income, and the stocks and flows of household assets.

A livelihoods approach to impact assessment (IA) augments the conventional practice of assessing impact because it captures a wider range of factors that affect the livelihoods of farmers than conventional IA, which often only examines improvements in crop productivity and returns. Taking this innovative approach, CIMMYT recently completed two studies on the impacts of maize research in the hill regions of Mexico and Nepal. The two case studies provide lessons for assessing impact through a livelihoods lens to complement economic assessments. The research projects and the present impact study generated a number of International Public Goods: methods for spatial analysis, methods for participatory research with farmers applied to IA, and capacity-building of farmers in maize selection and for IA research based on a livelihoods approach.

The first study, described in depth in this paper, assesses the impacts of research by CIMMYT and a Mexican partner, *Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias* (INIFAP), during the late 1990s in the Central Valleys of Oaxaca, Mexico. The objectives of this research were to raise productivity, preserve the diversity of traditional *criollo* maize landraces, provide training, demonstrate maize production practices, and promote post-harvest technologies.

In 2006, a study was launched to assess the impacts of this research, to examine the changes in farmers' livelihoods that resulted from the project, and to learn how such research projects can have more impact in the future. The study sought to capture the impacts of the project, in terms of the use of *criollo* maize, the use farmers made of training, and the use of post-harvest technology (silos). This was done by collecting and analyzing data on indicators of farmers' livelihoods and economic status. The results were examined for participant and non-participant farmers, and for different household wealth categories characterized through the IA study itself.

Reducing poverty by developing and selecting local and improved maize germplasm was just *one* of the goals of the research project. Other important objectives were to expand the knowledge on maize diversity, and generate and test participatory research methods. Although the benefits of these are hard to quantify, the IA should take account of these effects in the overall assessment.

The second study, to assess the impacts of the Hill Maize Research Project (HMRP) in Nepal, used a similar mix of qualitative and quantitative tools to those used in the Oaxaca study. In Nepal, CIMMYT and partners developed and tested improved varieties through participatory research. The Nepal study captures the outcomes and impacts of the participatory research projects in terms of maize productivity, food security, community-based seed production, empowerment, social inclusion, and the institutionalization of participatory research.

The Mexico study in the area of origin of maize indicates that there is a moderate use of improved maize and some impact on poverty, but that the area of maize has shrunk and that maize is less important as a commercial crop. In contrast, improved maize varieties in Nepal play an increasingly important role in improving livelihoods. In Nepal maize is also a way of improving the livelihoods of marginalized farmers in the hill areas, and low-caste women.

Acronyms

BMZ	Bundesministerium für Wirtschaftliche Zusammenarbeit and Entwicklung (German Federal Ministry for Economic Development Cooperation)
CBSP	Community-based seed production
CIMMYT	Centro Internacional de Mejoramiento de Maíz y Trigo (International Maize and Wheat Improvement Center)
DREAM	Dynamic Research Evaluation for Management (model)
ES	Economic Surplus analysis (method)
ESRI	Environmental Systems Research Institute
FGD	Focal Group Discussion (method)
GIS	Geographical Information Systems
GM	Gross Margin analysis (method)
GPS	Global Positioning System
HMRP	Hill Maize Research Project
ha	Hectares
INEGI	Instituto Nacional de Informacion Estadística y Geografía (The Mexican National Institute of Informatic and Geographical Statistics)
INIFAP	Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (Mexican National Institute of Foresty, Agriculture, and Livestock)
MXN	Mexican Pesos
NARC	National Agricultural Research Council (Nepal)
NN	Nearest neighbor matching (method)
NPR	Nepali Rupee
PDA	Portable Digital Assistant
PSM	Propensity score matching (method)
PVS	Participatory varietal selection
SDC	Swiss Agency for Development and Cooperation
SEDESOL	Secretaría de Desarrollo Social (Mexican Secretariat of Social Development)
TRMM	Tropical Rainfall Monitoring Mission

Introduction

To fully assess the impact of new technologies on farmers we need to shift the focus from 'crops' or 'commodities' to the impact pathway which links improved crop germplasm and management to household well-being. Household well-being includes factors such as food security, more income, and the stocks and flows of household assets. A livelihoods approach takes into account several of the factors that affect household well-being, and provides a way of examining diverse influences, thus ensuring that the key influences are captured.

CIMMYT recently completed two innovative impact assessment (IA) studies, in Mexico and Nepal, which used a livelihoods approach in order to capture impacts comprehensively. The livelihoods approach was used in conjunction with conventional economic and other tools. This paper compares the approaches, findings, and lessons learned in these two studies.

The Oaxaca study is a full livelihoods IA study. The Nepal study is partly a research study but mainly an external IA of the Hill Maize Research Project (HMRP). The Central Valleys of Oaxaca and hill areas of Nepal are similar in that they are both hilly regions where communities are relatively marginalized. Agriculture in both areas is rainfed, productivity is low, and infrastructure is poor, especially in Nepal. Populations are relatively poor by international and national standards, and have relatively low levels of natural, physical, human, and financial capital. Peoples' livelihoods are complex and highly vulnerable. A significant share of income is from off-farm. Men work outside the communities and women play key roles in farming.

Oaxaca, Mexico

In Oaxaca state, one of the poorest in Mexico, most rural people are indigenous. Maize is the traditional food crop. Maize originated in Mexico and Mexico is the center of maize biodiversity. Oaxaca hosts much of this biodiversity, thanks to farmers who have managed and conserved maize landraces through the centuries. Maize plays a special role in the life of local people, embodying concepts of food and survival. Maize is a mainstay of the traditional economy, as well as of people's culture and traditions. Although the Oaxaca Central Valleys are ethnically diverse and heterogeneous in their agro-ecology, all have experienced economic, cultural, social, and political changes in recent years, also because of the globalization of food industries and markets. There is steady out-migration, as young people are leaving agriculture and agricultural knowledge is lost. Agriculture is becoming marginalized and maize is becoming less important as a commercial crop. But local people still use maize for consumption, and maize remains culturally important.

Traditional farming practices are also changing. Migrant farmers have started to introduce new crops or maize hybrids. These may affect maize diversity and the economic competitiveness of maize. But it is important to preserve the *criollo* varieties (selected by farmers over generations) because they have traits, for instance tolerance to drought, which can be drawn on to generate improved varieties for farmers well beyond the Central Valleys and throughout Mexico.

From 1996-2001 CIMMYT and the Instituto Nacional de Investigaciones Forestales, Agricolas y Pecuarias (INIFAP) worked in the Oaxaca Central Valleys to explore how scientists and farmers could work together to conserve maize diversity. The title of the project was *Maize Diversity Conservation: A farmer-scientist collaborative approach in Oaxaca,* henceforth referred to as the Oaxaca Project. The project worked to improve farmers' livelihoods by conserving maize in situ, exploring possibilities for improving productivity (yield and stability), and preserving diversity. Improving maize productivity and farmers' livelihoods, however, was just *one* of the goals of the project. Other goals were to build up knowledge of maize diversity and generate and test participatory research approaches (e.g. Bellon 2001).

The first study assesses the impact of the Oaxaca Project, particularly the changes in livelihoods linked to project activities, changes in productivity and preserved diversity of traditional *criollo* maize landraces, the impacts of training and demonstrations offered by the project, and of the promotion of post-harvest technologies. The Oaxaca study draws lessons on how to effectively implement an IA within the framework of a livelihoods approach. This was particularly relevant when the study was being done as, at that time, IA at CIMMYT was being reshaped to meet new demands. The Oaxaca Project generated options for small-scale farmers to benefit from genetic diversity in local traditional landraces. Components of the project included a) a baseline and diagnostic assessment of maize diversity and household features (Smale et al. 1999; 2003), b) research and extension interventions, including field days, demonstrations, training, seed sales, promotion of post-harvest technology, collection and sale of *criollo* maize, and c) a program to monitor performance of the interventions.

Initially, the selection of communities to participate in the Oaxaca Project was based on agro-ecological and socio-economic criteria. Most project activities took place in six representative communities classified into three strata: rich, intermediate, and poor. Later in the project (e.g. Badstue et al. 2006) most activities focused on three communities, one in each strata (Figure 1): San Pablo 'Huitzo' (rich); 'Santa Ana' Zegache (intermediate); 'San Lorenzo' Albarradas (poor).

The Oaxaca Project established demonstration plots. Sample households were identified for a 1998 baseline socio-economic and maize diversity survey. During the project farmers received training on: a) evaluating maize reproduction and maize improvement, b) the principles of maize reproduction, c) field and home seed selection, and d) techniques to store seed and grain.

Nepal, Hill Maize Research Project (HMRP)

Maize is grown in the hills and *terai* (plains) regions of Nepal, in a wide range of agro-ecological and climatic conditions, and farming systems (Figure 2). Maize, the staple food of hill farmers, is grown on terraces in the low, mid- and high hills under rainfed conditions during the summer. Irrigated maize is also grown in the alluvial plains of the *terai* valleys and low-lying river basins in spring and winter. Maize productivity is low. The average yield is 1.8 tons/ha. This may be

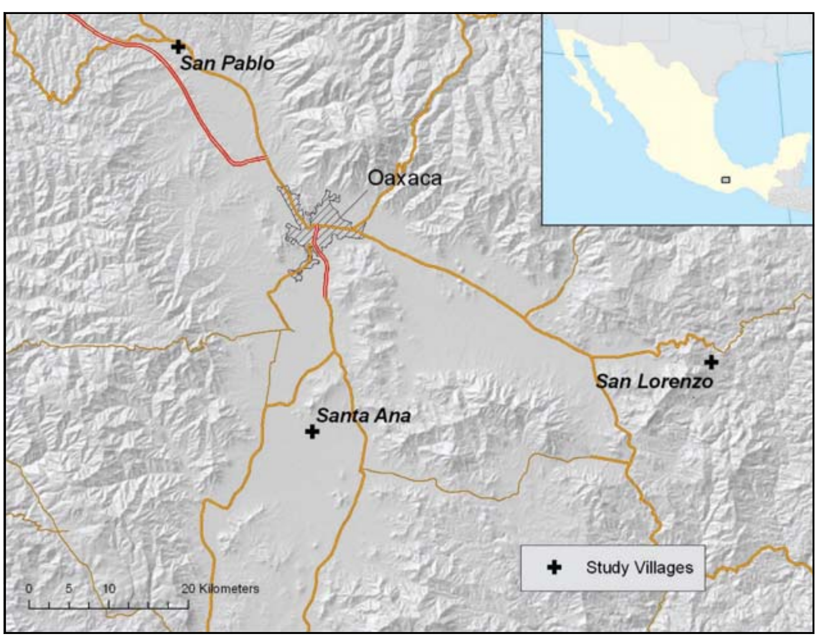

Figure 1. Map of the 2006 impacts study research area in Oaxaca (see color plates inside front cover).

attributed to both biotic (e.g. pests, diseases) and abiotic factors. Nepal's National Maize Research Programme (NMRP) is mandated with developing suitable technologies to increase the productivity of maize in different agro-ecologies through a coordinated research approach.

The Hill Maize Research Project (HMRP) was established as a tripartite research and development project between Nepal's National Agricultural Research Council (NARC), CIMMYT, and the Swiss Agency for Development and Cooperation (SDC). HMRP implemented and coordinated project activities, and CIMMYT provided technical expertise, germplasm, training, and administrative support. HMRP was implemented in two phases. Phase I ran from 1999 to 2001. In this phase, the emphasis was on boosting the incomes of farm families in the hills of Nepal and making them more food secure. This was to be done by raising the productivity and sustainability of maize-based cropping systems. The outputs of the project included new maize technology, dissemination of new maize varieties through participatory varietal selection (PVS) and community-based seed production (CBSP), stronger capacity in maize research and production, and stronger links with partners.

The outcomes of Phase I justified funding for a second phase, Phase II, which ran from January 2003 to December 2007.

The objectives of the HRMP were developing capacity to generate maize production technology, developing technologies with and for poor maize farmers, and disseminating maize technologies through extension. The focus was on technologies that could be directly transferred to, and used by, poor maize farmers, and would reach the most marginalized and vulnerable social and economic groups, the *dalits*, *janajatis*, and women. The project actively involved the poor and typically excluded groups of women, and reached out to other marginalized and excluded social groups. This countered the lack of access to public services in the study areas, which is largely driven by social identity such as caste, ethnicity, gender, economic status, and physical location.

Mathema and Gurung (2006) assessed the impacts of HMRP in terms of improving maize productivity, food security, livelihoods, empowerment, social inclusion of Nepal hill farm families, and institutionalization of participatory research.

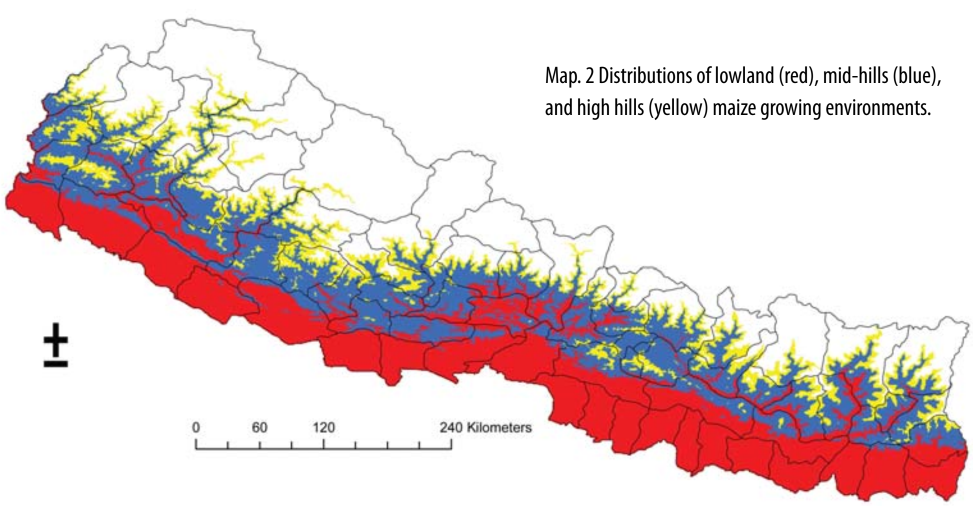

Figure 2. Location of mid-hills and high hills maize-growing areas, Nepal (see color plates inside front cover).
From Paudyal et al. 2001. Mid-hills in blue, high hills in yellow.

Maize research projects as generators of International Public Goods

International Public Goods (IPGs) are defined as "*research outputs of knowledge and technology generated through strategic and applied research, applicable (and readily accessible) internationally to address generic issues and challenges consistent with the CGIAR*" (Harwood et al. 2005). Such goods generated through the project are non-rival and non-excludable, meaning that their use by an individual does not reduce the amount available to others, and no one can be excluded from using them (see Ryan 2006)[1].

The International Public Goods generated by the two research projects in Mexico and Nepal are:

– *Maize varieties and diversity options, and maize post-harvest technology*. These are ment to reach farmers in marginal mountainous areas, boost food production, facilitate crop diversification, and contribute to sustainable production. In Mexico, the Oaxaca Project aimed to increase productivity, preserve diversity, and promote post-harvest technology. In Nepal, the projects developed technologies with and for poor maize farmers.

– *Strengthened capacity of partners and farmers in maize diversity.* In Mexico the training and demonstrations of the Oaxaca Project strengthened farmers' capacity. In Nepal the HMRP project strengthened partners' capacity for generating maize technologies.

– *Generating, institutionalizing, and scaling out participatory research approaches.* In both Mexico and Nepal the projects tested and/or out-scaled methods of participatory research with poor marginal maize farmers. In addition, in Nepal, the project facilitated the dissemination of new maize technology, focusing particularly on socially excluded groups.

[1] Research on the themes of these research projects, additionally, does not reduce the amount of the products of research available to others, and people cannot be excluded from using them. Such goods are known, available, accessible by partners, and applicable. Also, although such research was developed in two countries—Oaxaca is sub-national, Nepal is national—the lessons and outputs are available internationally.

The Oaxaca IA study used, and at the same time tested and piloted, *new tools for socio-economic research.* One tool was the use of Personal Digital Assistants (PDAs) for collecting real-time data for IA (Carrion and La Rovere 2007). Another was an innovative approach for collecting geo-referenced plot data directly on farm using web-based Google Earth™ technology. A third was the analysis of satellite-derived data for climatic patterns (see full description in Annex 1).

Methodology and materials

Framework of the study

CIMMYT uses the 'livelihoods approach' as a 'check list' of important issues to be considered in doing an IA, to choose and design impact indicators, and to understand how they link to one another. The livelihood dimensions considered are: food security, lack of assets, risk, and vulnerability. The livelihoods approach also draws attention to influences and processes, and emphasizes the multiple interactions between the various factors which, in practice, affect livelihoods. IA is increasingly attempting to capture different types of impacts (direct, indirect) and more of the successes, and to build more meaningful impact stories. In addition, IA should help us learn from past research outcomes. This means that IA must go beyond aggregating economic benefits, and must integrate additional analytical tools. Conventional economic approaches mostly assess adoption; yet adoption is only *part of* the impact picture and actually only 'assumes' *real* impact. La Rovere and Dixon (2007) and Walker et al. (2008) discuss implementing these types of IA, and livelihoods approaches within multi-dimensional IAs.

The IA studies described here adopted a livelihoods approach, supplemented in the Nepal study with surplus analysis, and stakeholder and gender assessment, and in the Mexico study with econometrics. In both cases the IA considers food security and income enhancement. The Mexico study looked back explicitly ex post to work done a decade before. As the HMRP project was still in progress, the independent external IA study combined ex-post assessment and monitoring.

Oaxaca, Mexico

In Oaxaca the impacts study was completed between late 2006 and early 2007 in the same three communities of Badstue et al. (2006): Huitzo, San Lorenzo, and Santa Ana. The preliminary appraisal confirmed that these communities were representative of the communities that were part of the Oaxaca Project in the late 1990s. The impact study applied the livelihoods approach in conjunction with econometrics and gross margin analysis. Focal group discussion (FGD) and key informant surveys generated qualitative data which were used to triangulate quantitative data. Household data were collected by semi-structured questionnaires programmed into Personal Digital Assistants (PDAs, see Carrion and La Rovere, 2007, for the advantages and disadvantages experienced in the field). The methods for collecting and analyzing data on farm using Google Earth™ are described in the Annex. We used econometric clustering, based on Hierarchical Cluster analysis and Two Step cluster analysis, to group households into homogeneous types (La Rovere et al. 2007), based on 13 livelihood assets (Table 1), 11 quantitative and 2 qualitative, belonging to all livelihood capitals: natural and physical, financial and economic, human and social.

We used data from Smale et al. (1999; 2003) as a baseline. For the 2006 impact study we interviewed the 'participants' and 'non-participants' in the Oaxaca Project and assessed changes in quantifiable livelihood indicators. However, only a few indicators in the Smale et al. (op. cit.) studies are directly and explicitly comparable with the livelihood indicators chosen in 2006.

We measured the impact of the Oaxaca Project by comparing the data for the indicators chosen for the 1998 baseline study with data for similar indicators chosen for the 2006 assessment (this being the 'before/after' the project counterfactual). We recorded qualitative data on the impact of the Oaxaca Project and changes in livelihoods by analyzing the *perceptions* of farmers through FGDs. The present study revisited the same participants of the Oaxaca Project to find out what had happened to them in the meantime. However, by 2006, only 68 of the original participants were still around, and only 52 of these had been part of the baseline study (Smale et al. 1999). Fifty-two new households were randomly selected as a control to make up the 'with/without' counterfactual, based on comparing 'participants' and 'non-participants' in the project.

We analyzed the gross margins for the 12 farmers who had cultivated both *criollo* and CIMMYT selections of maize since 1998. The gross margin analysis took account of all production and post-harvest costs, and the values of all outputs, per hectare. As maize is often intercropped with beans and pumpkin, the value of beans and pumpkin was considered separately. The opportunity cost of labor was not included as farmers reported only on-farm labor.

We used a Propensity Score Matching (PSM) procedure to assess whether the value of maize production—as an indicator of factors that contribute to food security and poverty—was influenced by the project interventions: adoption of CIMMYT maize selections, adoption of silos for post-harvest storage of maize, and participation

Table 1. Livelihood typologies and selected livelihood indicators, Oaxaca.

Type of household	Very poor	Poor	Middle poor	Better off	Total
Number of households	33	31	37	19	120
Percentage of total	28%	26%	31%	16%	100%
Average land endowment (ha)	2.17	4.79	3.11	6.37	3.80
Quality of parcels (good/medium/bad)	1/17/15	1/19/11	10/16/11	7/8/4	N.A.
Irrigation (households with/without)	0/33	0/31	37/0	13/6	50/70
Inputs used (average number of)	2.06	3.19	3.08	3.63	2.92
Equipment (average number of)	1.73	3.58	3.22	4.00	3.03
Distance to markets (minutes)	100	136	81	72	99

in capacity-building activities. The PSM approach controls for the self-selection that normally arises when technology adoption is not randomly assigned. A key issue in evaluating the impact of adoption on income is specifying the average treatment effect. Rosenbaum and Rubin (1983) define the impact of adoption on income (Δ_i) in a counterfactual framework as $\Delta_i = Y_i^A - Y_i^N$ (1) where Y_i^A and Y_i^N are the incomes of a household, *i*, when it adopts the technology and when it does not adopt it. In estimating the impact from (1), a problem is the fact that, for each household, either Y_i^A or Y_i^N would normally be observed, but not both. What is normally observed can be expressed as:

$$Y_i = D_i Y_{iA} + (1 - D_i) Y_{iN} \quad D = 0,1$$

Where Y is the potential outcome and D is a 0 or 1 dummy, binary, variable for the use of the new technology; $D_i = 1$ if the technology is adopted and $Di = 0$ otherwise.

When the data available provide no information on the counterfactual, a missing data problem arises. In this case, the direct effect of technology adoption from the variation in outcomes across households must be estimated, using statistical PSM (Abadie et al. 2004; Caliendo and Kopeinig 2005). PSM estimates the effect of adoption for the full sample from the weighted average of the effect of adoption for adopters (treated) and non-adopters (controls), where the weightings are the relative frequencies. Matching the treated and the control subjects becomes difficult when there is a multi-dimensional vector of characteristics. The PSM solves this type of problem by summarizing the pre-treatment characteristics of each subject into a single index variable, and then using the propensity score (PS) to match similar individuals. This constitutes the probability of assignment to treatment conditional on pre-treatment variables (see Rosenbaum and Rubin 1983; Becerril-García 2007). There are a number of methods for matching similar adopters and non-adopters, such as nearest neighbor matching (NN), used here to calculate the average treatment effect by matching each treated individual with a control with the closest PS. Then, the difference between the household incomes for each matched pair is computed. A relevant application in agriculture is in Mendola (2007).

In our study Y is equal to the value of maize production as an indicator of income that contributes to food security and poverty reduction. Y is influenced by adoption of CIMMYT maize selections, adoption of silos for post-harvest maize storage, and participation in capacity-building activities. The PSM method estimates impacts by comparing the outcomes Y of a treatment group (adopting the technology) with the outcomes Y of a control group (the non-adopters). The *comparison group* is identified from a sample of potential comparison group members using the PS, which indicates the extent to which one person is similar to another according to observed characteristics. The PSM uses Probit estimations for each intervention. Most variables in our cluster analysis were used as independent (covariates): number of family members, their ages, gender (female), education of household head; number of chickens, equipment used, oxen available, and area of land; amount of inputs, irrigation, and time to the closest market.

Hill Maize Research Project (HMRP), Nepal

In 2006, Mathema and Gurung (2006) carried out an external assessment of the impact of the HMRP. The assessment compared livelihood indicators in project areas (with) and non-project areas (without), and changes in indicators before and after the project. The assessment looked at two areas: a project area and a similar non-project area. To compare livelihoods before and after the project, data were collected from beneficiary households in different socio-economic groups from 10 locations. Data were collected from secondary sources, participatory rural appraisal, and directly from partners and stakeholders. Baseline data were collected ex post using the recall method. The study assessed impacts on socially disaggregated groups: the *dalits*, the *Brahmin*, *Chhetri*, and *Newar* (BCN)[2], and the *janajatis*. The study included gross margin and economic surplus analyses. Direct impacts of the project were lower costs, new technology, and

[2] BCN= Brahmin, Chhetri and Newar are considered to be advantaged castes and ethnic groups.

better seed production. Indirect impacts were, for example, empowerment, social inclusion, and more social equity for poor, geographically remote and excluded groups[3]. In Nepal it is the poor women who constitute an important impact pathways in achieving impact in rural areas.

We estimated the benefits of adopting maize technology for producers and consumers, and the profits of individual farmers from three-year time-series data in 10 different places, using the Economic Surplus analysis (ES) and Gross Margin analysis (GM). Focus group discussions (FGDs) in all locations elicited data on annual growth rates of maize productivity, and the trends in total maize production and consumption. Detailed information on input costs and benefits of growing maize was collected from key informants. As new maize technologies either raise crop productivity or lower marginal production costs, technological changes also contribute to higher total maize production. Adopting new maize technologies can thus benefit both producers *and* consumers (more maize in the market and lower prices in the villages). We estimated economic surplus using the Dynamic Research Evaluation for Management (DREAM) software (Wood et al. 2001). Gross Margin analysis estimated the profitability of the introduced maize technologies and compared profitability of introduced maize technologies with that of prevailing practices.

Results

Oaxaca, Mexico

Livelihoods

An 'ageing' process of farming was found in the area, also due to migration. Average farm size has been increasing, mainly by expanding onto poor quality land. The area planted with maize has declined. Although the studies conducted in the late 1990s found that "by some indicators of wealth households were not poor," in 2006 about 28% of households were found to be poor and marginalized. These were households with poorly educated older farmers, who were also still growing maize as their main food. Remittances are an important source of household income: from Mexico for poor families, from the USA for richer ones. At the end of the 1990s remittances averaged 20% of total income, ranging from 10% of total household income in the most advanced, market-connected community to 25% or more in the other two communities.

Maize production

For the households that were sampled in 2006, we compared the changes in average yield from 1999 to 2006 where data were available. Households that had bought CIMMYT selections experienced moderate decreases in average yield (11%). Those who did not buy CIMMYT selections experienced larger losses (19%). Average 1999 yields were in line with those of 2006, hence in general terms findings did not confirm the farmers' *perceptions* of declining yields.

Maize diversity

Farmers' preference for certain varieties of maize is often linked to food preferences. They prefer the white (*blanco*), yellow (*amarillo*), or blue (*negro* or *azul*) maize varieties. As compared to the late 1990s, in 2006 most farmers still preferred *blanco* maize because it has a good market, is preferred for eating, and is drought tolerant. With regard to biodiversity, they did not report large losses of maize populations. Only one variety (VC-152) from the Oaxaca Project was considered to be good for eating and for feeding to animals and was still present. Improved maize is grown only in Huitzo, the most advanced and market-connected community. In the more remote communities that are least connected to markets, most farmers are poor and adopted CIMMYT selections more often. Table 2 compares the situation in the late 1990s with the situation in 2006.

Maize use

In 2006, 27.5% of farmers out of the whole sample were still using maize derived from the Oaxaca Project (CIMMYT selections are local varieties that were selected by farmers during the project[4]). Of

[3] Excluded groups: women, *dalits*, and *janajati* groups (except Newar and Thakali, which are seen as advantaged).

[4] These do not include varieties from CIMMYT germplasm bank; CIMMYT only facilitated the selection.

Table 2. Livelihoods, maize production, and maize diversity in the late 1990s and 2006.

Indicators	Situation in late 1990s	Situation in 2006
Livelihoods and farm household	*Household average size 5.25 members. Mean age of farm heads 50 years.*	Average household size declined to 4.32 members. Average age of principal household member increased to 60 years.
	Average farm size 3 ha. Average maize area 2.55 ha. By some indicators, households are not poor.	Average farm size increased to 3.81 ha. Maize area declined to 2.20 ha. Poorer households are 28% of total.
Maize production	*Average yield of maize in 1999 in households for which we were also able to collect data in 2006 was 651 kg/ha, ranging from 513 to 905 kg/ha across the study communities.*	Average yield in 2006 was 647 kg/ha, ranging from 502 to 890 kg/ha across the study communities. Farmers with CIMMYT selections had lower (11%) yield losses than those without (19%).
Maize diversity	Blanco *maize occupied over 80% of the area given over to maize production and represented two-thirds of the seed lots in 1997. Subjective yield distribution suggests that improved maize dominates over local types.* Blanco *dominated the colored grain types. Improved maize is grown only in the most advanced community.*	In 2006 most farmers were still using *blanco* maize (51%), though fewer than in 1999. There was a shift to *blanco delgado* (25%) and *blanco ancho* (10%). Some maize varieties in use in the late 1990s are not used today. The community with the best connections to market is still the only one where improved maize is grown.

those who participated in the project, 44% still use CIMMYT selections. In addition, 5.8% of those who did not participate also grew maize from the project, suggesting some spontaneous farmer-to-farmer diffusion of maize selections. Maize that farmers had bought from the project, however, had often got lost, mainly due to drought. But many farmers are still using varieties derived from the crosses made in the field or from mixes of *criollo* varieties. The main advantages of CIMMYT selections from the farmer's point of view are that they are better for consumptiom, and that yields are higher. Disadvantages are that the growth cycle is longer and they are more difficult to market.

Yields and gross margin

CIMMYT selections have outperformed local *criollo* maize every year since 2001 on the farms of the subset of the 12 households which participated in the project and were still planting both *criollo* and CIMMYT maize in 2006 (Figure 3). CIMMYT selections outperformed *criollo* maize (Table 3) by 10% for minimum yield, by 14% for maximum yield, and by 16% for mean yield.

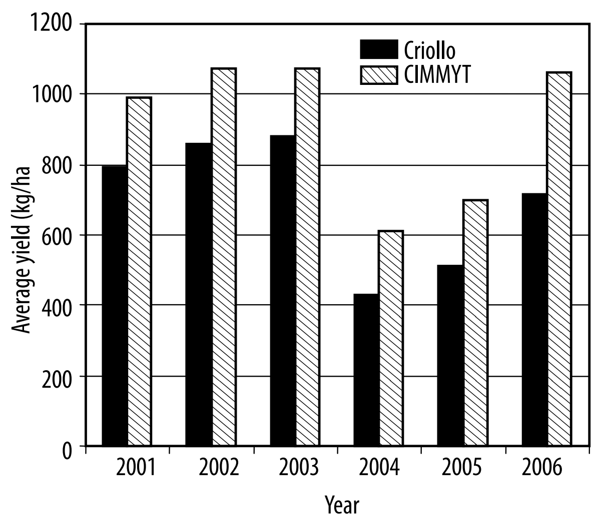

Figure 3. Yields of *criollo* and CIMMYT selections of maize in Oaxaca, Mexico, 2001–06.

Maize yield (Table 3) is very variable as it depends on factors such as soil quality, availability of labor, use of fertilizer, and time of sowing. Based on the value of maize products[5], the gross margin of CIMMYT selections ('with' the project) is

[5] As maize is intercropped with beans and pumpkin, the total gross margin after including the value of these two crops are respectively MXN2,620/hectare for areas planted with CIMMYT selections of maize (and beans and pumpkin) and MXN1,199/hectare for areas planted with *criollo* maize (and beans and pumpkin).

Table 3. Average maize yields, Oaxaca, 2001–06.

Yield (kg/ha)	*Criollo* maize	CIMMYT maize
Minimum	312	344
Maximum	1,284	1,462
Most frequent	690	803

MXN1,857 (USD172) per hectare, while for *criollo* maize ('without') the gross margin is MXN627 (USD58). Normally, the household consumes the maize that is not sold. Thus, although in real terms maize is not very profitable, farmers keep growing it for consumption and to use the crop residues as forage for livestock.

Use of CIMMYT selections of maize
Farmers growing CIMMYT selections of maize appear to have more land than those who do not grow CIMMYT selections, but their yields are lower. The farmers who participated in the Oaxaca Project were often those whose incomes were lower, those who were older, and those with larger families. The average yield was lowest (427 kg/ha) for the 'very poor' group, who own the land of poorest quality. The farmers with higher incomes use improved seed more frequently and get higher yields. They grow very little *criollo* maize.

Maize post-harvest technology (silos)
Nearly one-fifth (17.5%) of farmers have at least one silo. More than half the farmers who bought silos did so through a process facilitated by CIMMYT. Farmers invested in silos because they are easy to use, affordable, are a good replacement for traditional practices, and because they meet the need to reduce losses and store food securely. Silos are a pro-poor food security option that has diffused from farmer-to-farmer. The farmers who adopted the silos were those who were younger and more educated, and those who were better informed about support programs.

Use of learned techniques
Participants in the Oaxaca Project gained skills and knowledge from CIMMYT training (e.g. on open pollination, types of *criollo* maize, seed storage methods, use of agrochemicals). However, farmers reported that much of their learning had dissipated and relatively little of what had been learned had been applied. Techniques learned during the project had been applied only to a moderate extent, as the practices were labor intensive when compared to traditional practices.

Impact of CIMMYT interventions based on Propensity Score Matching
Table 4 shows the results of the Probit models. The variables that negatively influence the probability that CIMMYT selections will be adopted are those related to social capital (n of family members, age, and education of head of household). Only two variables were statistically significant: the (female) gender of the household head and the n of input used. Both these variables were associated with an increased probability that CIMMYT selections would be adopted. It is the women who look for specific characteristics in the CIMMYT selections of maize and who choose to adopt them for these characteristics. Farmers wanting to raise maize production tend to adopt and use varieties that give better yields and are more adapted to their environment. They also use more inputs.

Significant variables that negatively influence adoption of silos are the age of the household head and the number of inputs used. Age has a negative effect because older farmers are more reluctant to use new or different technologies than younger farmers. The number of inputs used has a negative effect because farmers who use more inputs get 'higher' yields and, so, have more to sell, and less need of silos to preserve maize for consumption. The n of equipment use has a positive influence on adoption of silos since farmers who get low yields tend to rely on better agronomic practices rather than on higher input use. Farmers who have the resources to buy inputs and use equipment are those more likely to try to make their production more efficient and to participate in capacity-building activities. The variables that influence farmers' participation in capacity-building activities positively and significantly are the n of inputs and equipment.

We estimated the impact of CIMMYT interventions based on the average treatment effect using the PSM method for each of the interventions, with

Table 4. Probit model results to estimate Propensity Score for CIMMYT interventions.

	CIMMYT selections			Silos			Capacity-building		
	Coef.	Std. Err.	z	Coef.	Std. Err.	z	Coef.	Std. Err.	z
Household members (n)	-0.120	0.079	-1.53	-0.150	0.102	-1.47	-0.095	0.073	-1.31
Chickens (n)	0.002	0.015	0.12	0.015	0.020	0.72	0.023	0.016	1.40
Total land area	0.024	0.043	0.56	0.039	0.050	0.78	0.020	0.043	0.48
Age household head	-0.004	0.018	-0.25	-0.037	0.022	*-1.68	-0.002	0.016	-0.11
Gender (female)	0.635	0.338	*1.88	0.569	0.465	1.22	0.364	0.347	1.05
Education household head	-0.023	0.083	-0.27	0.090	0.106	0.85	-0.024	0.076	-0.31
Inputs used (n)	0.223	0.110	**2.02	-0.246	0.144	*-1.71	0.344	0.111	***3.10
Equipment used (n)	0.101	0.097	1.04	0.550	0.145	***3.79	0.179	0.097	*1.85
Time to market	0.003	0.002	1.19	0.001	0.003	0.34	0.002	0.002	0.83
Irrigation	0.112	0.306	0.37	-0.664	0.413	-1.61	-0.433	0.289	-1.50
Oxen available	0.014	0.278	0.05	-0.042	0.349	-0.12	-0.141	0.285	-0.49
Constant	-1.344	1.347	-1.00	0.133	1.640	0.08	-1.036	1.291	-0.80

Significant at * 10%, ** 5% *** 1% level

respect to three outcome variables: the monthly per capita value of maize production, ratio of the value of maize production to total income, and poverty. Households were classified according to the clusters classification derived from this study and from the national Secretaría de Desarrollo Social (SEDESOL) lines for Mexico (Table 5, World Bank, 2004). Because the interventions of the Oaxaca Project help to either increase or maintain current maize yields, the impact of the project is reflected in the estimated value of maize production. Likewise, we estimated the proportion of the value of maize production over total income. Poverty, as defined in the clusters and the SEDESOL poverty lines, was represented by binary variables (poor = 1, non-poor = 0).

The income averages in both cases (clusters classification derived from this study and from SEDESOL) are similar (Table 5). Farmers in the first three clusters of our classification are considered as poor (very poor, poor, middle poor), and farmers in the 'better off' cluster as non-poor. Likewise, the SEDESOL lines classified poor farmers in three poverty levels (food poverty, capacities poverty, asset poverty) and classified the farmers with higher incomes as non-poor.

Adoption of CIMMYT maize selections

Based on the NN (nearest neighbor) matching method we assessed the causal effect of participating in CIMMYT interventions. The impact of adopting CIMMYT selections on the value of maize production (Table 6) was significant, generating a production value advantage of ~MXN107 (the average difference in the value of maize production that adopters of CIMMYT selections get, as opposed to non-adopters). CIMMYT selections had a significant and positive causal effect on the contribution of maize production value to total income, generating a 24.3% advantage for adopters compared with non-adopters. We applied the same procedure to estimate the probability that the adoption of CIMMYT selections contributes to reducing poverty. With respect to the SEDESOL poverty lines, the result was negative as expected (-6%), suggesting that adoption is associated with less poverty (though not statistically significant). With respect to the clusters from this study, the result was also negative (-18%), but significant. This means that adoption is associated with less poverty for adopters when compared with the non-adopters.

Adoption of silos for post-harvest storage

Although none of the outcomes for the silos intervention were statistically significant, in most cases the results were as expected. In terms of the value of maize production (Table 6), there was no difference between farmers who adopted silos and those who did not adopt. The effect of adopting silos was negative on the contribution of the value of maize production to total income. This suggests that because silos are intended to reduce post-harvest losses, adopting them has no effect on increasing the value of production. So, the CIMMYT silos technology did not have any effect on poverty in terms of differences among treatment and control groups based on SEDESOL poverty lines. But, in terms of the clusters classification derived from this study, the CIMMYT silos technology did reduce poverty, although the coefficient is not significant.

Capacity-building

The causal effects of capacity-building interventions were as expected, although not significant. Farmers who participated in capacity-building activities had higher maize production value than those who did not. The contribution of maize production value

Table 5. Poverty classifications of the sample households in Oaxaca, Mexico.

Derived from clusters classification in this study and SEDESOL lines for Mexico.

MXN/capita/month	Total income (A) (MXN/month)	Maize production value (B) (MXN/month)	Ratio B/A
	Cluster-based poverty lines (present study)		
Very poor	611	158	0.25
Poor	750	245	0.39
Middle poor	872	308	0.49
Better off	1,124	535	0.86
	SEDESOL-based poverty lines (World Bank, 2004)		
Food poverty	332	280	0.45
Capacities poverty	701	330	0.53
Patrimony poverty	896	332	0.53
Non-poor	2,288	239	0.38

Table 6. Effects of CIMMYT interventions on production value of maize, income, and poverty.

Variable	CIMMYT selections	Silos	Capacity-building
Per capita maize production (MXN/month)	107	1	89
	(1.72)*	(0.01)	(1.10)
Maize production value/Total income (%)	24.3	-10.4	13.8
	(1.91)*	(-0.50)	(0.84)
Poverty - SEDESOL lines (%)	-6.1	0.00	-4.4
	(-0.87)	(0.00)	(-0.33)
Poverty - CIMMYT clusters (%)	-18.2	-9.5	-17.6)
	(-2.10)**	(-0.48)	(-1.50
Observations			
Treated (Adopter)	33	21	68
Controls (Counterfactual)	87	99	52

Significant at * 10%, ** 5% level; t-test in parenthesis.

to total income showed similar results. For both SEDESOL and clusters poverty classifications the coefficients were negative, meaning that participation in capacity-building activities contributed to reducing poverty.

Hill Maize Research Project (HMRP), Nepal

Mathema and Gurung (2006) found that the HMRP has had several impacts.

Livelihoods

During the project, scientists trained farmers in improved maize cultivation practices and encouraged participatory varietal selection (PVS) field trials, as well as community-based seed production (CBSP). The PVS field trials involved 45% women, 40% *dalit*, and 15% *janajati*. For the purposes of the HMRP, participants were classified into three economic strata in terms of food sufficiency: rich, with a food surplus for the whole year; middle, with food for 6–9 months and; poor, with food for less than 6 months. Of those involved in PVS, 66% were in the poor group, 22% in the middle group, and only 14% in the rich group. Seed production groups involved *dalits (20%), janajatis (22%), and women (58%)*. Females from all economic strata and resource-poor farmers participated in marketing maize seed, thanks to the community-based seed production (CBSP) groups. The income from maize production is mainly spent on minor household expenses and educating children. This means that targeting food-deficit households has a positive effect on improving the livelihoods and social equity of very poor farmers. Before the project, maize was grown mainly for household consumption but, recently, farmers have begun to sell it, helping to diversify their incomes. Mathema and Gurung (2006) reported that PVS and CBSP increased maize production by more than 50% compared to local varieties.

Use of maize varieties

The area and yield of improved maize varieties increased compared to local varieties at project sites. In 2006, 62% of the project area was sown with improved varieties. The average yield of improved varieties in 2005 was 2.96 tons/ha compared to 1.39 tons/ha from local varieties. Farmers preferred the improved varieties because the yield was higher, they liked the taste, the improved varieties were non-lodging, and they were more palatable as forage for animals. A major impact of HMRP germplasm testing was the release by the National Variety Release Committee in 2005 of the Deuti (ZM-621) and Shitala (Population-44) varieties recommended for the mid-hills of Nepal. Both varieties are white and have a potential yield of 4–5 tons/ha.

Food security

Household food self-sufficiency at nine field sites was assessed in 2002 (prior to Phase II) and 2006 (in Phase II). Figure 4 shows that the number of households that were food self-sufficient for 6–11 months and for more than a year had increased by 2006 when compared to 2002. The percentage of households which were food self-sufficient for one year or more increased from 11% to 24%. The project worked with about 8,000 farmers, of whom 49% where women and 51% were men. Of those farmers, 86% were in the food-deficit group. The majority (51%) were *Brahmin, Chhetri,* and *Newar* (BCN), 32% *dalits*, and 17% *janajatis*. Most were from poor households: 57% in the poor category, 29% in the middle one, and 14% in the rich one (Mathema and Gurung 2006).

The percentage of households self-sufficient in food for 6–11 months increased from 29.5% in 2002 to 42.6% in 2006. However, the percentage of

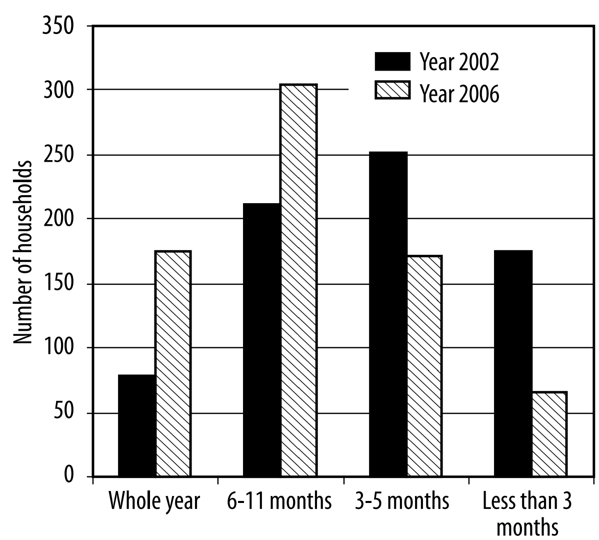

Figure 4. Food self-sufficiency of participants in HMRP, 2002 and 2006.

households self-sufficient in food for 3–5 months decreased from 35% in 2002 to 23.9% in 2006. The percentage of households self-sufficient in food for less than three months decreased from 24.4% in 2002 to 9.1% in 2006. Changes in household food self-sufficiency could be attributed to factors such as remittances and on-farm and off-farm employment, amongst others, as well as changes in productivity and lower risk.

Gross margin

Farmers adopting maize technology used quality seed provided by HMRP. Local maize seed has low productivity. The use of manure and chemical fertilizer was relatively low. Productivity when farmers practiced improved maize agronomy was higher compared to when they used local practices. The costs of production per hectare were estimated for improved maize (with) and local maize (without). The gross margins per hectare and per location are shown in Table 7.

The average gross margin for improved maize is higher than for local maize by NPR9,431 (about USD121). Incremental benefits accrue when inputs such as good quality seeds are used, higher doses of manure are applied, and outputs are sold at higher prices. Adopting maize technology generally involved more labor. Quality maize seed fetches 50% more than traditional maize seed at the market. Thus, farmers benefit financially by replacing local maize with improved maize.

Economic surplus

In the HMRP most farmers have now adopted improved maize, mainly grown for household consumption and as animal feed. Economic Surplus analysis showed that improved maize has benefited not only the maize producers (by increasing productivity) but also consumers (by making cheaper maize seed available in the villages). In general, the technological change in maize cultivation benefited producers by 64.35% and consumers by 35.65% (Table 8).

Table 8. Value of improved maize technology to producers and consumers, HMRP sites, 2006.

Districts and sites	Producer	Consumer	Total
Dolakha, Kirate Chhap	2,928.3	0.0	2,928.3
Sindhupalchowk, Thumpakhar	17,069.0	8,725.3	25,794.3
Dhankuta, Jimi1	613,727.7	391,889.4	1,005,617.1
Gorkha, Dandi Danda	14,661.1	0.0	14,661.1
Baglung, Kundule	61,896.7	0.0	61,896.7
Palpa, Chhatiwan	33,562.5	38,683.6	72,246.1
Palpa, Khaseuli	1,432.1	0.0	1,432.1
Gulmi, Simichaur	652.5	9,227.2	9,879.7
Dailekh, Fulbari	42,605.7	0.0	42,605.7
Dhankuta, Chhimsuwa	20,986.4	0.0	20,986.4
Total Net Present Value (NRs)	809,522.5	448,525.7	125,8048.2
Percentage (%)	64.35	35.65	100.0

Source: Mathema and Gurung, Field survey, 2006; In NPR: Nepali rupees

Table 7. Gross margin/ha for improved and local maize at HMRP sites.

District and sites	Gross Margin (NR)		Gross Revenue (NR)		Input Cost (NR)	
NPR: Nepali rupees	Improved maize (with)	Local maize (without)	Improved maize (with)	Local maize (without)	Improved maize (with)	Local maize (without)
Dhankuta, Chhimsuwa	14,262	5,237	19,514	10,491	5,252	5,254
Dolakha, Kirate Chhap	42,567	8,142	69,184	18,333	26,617	10,192
Palpa, Chhatiwan	50,805	10,785	85,397	27,145	34,592	16,360
Gorkha, Dandi Danda	14,474	(1,254)	32,629	12,006	18,154	13,260
Gulmi, Simpani	26,180	31,200	71,880	68,000	45,700	36,800
Sindhupalchowk, Thumpakhar	10,641	2,100	28,365	39,067	17,724	36,967
Dailekh, Ritha	16,124	13,087	28,889	18,667	12,764	5,580
Baglung, Kundule	19,350	6,580	69,500	55,650	50,150	49,070
Overall (Rs.)	**19,319**	**9,888**	**37,101**	**28,160**	**17,782**	**18,272**

Source: Mathema and Gurung, Field survey, 2006

Comparison of approaches and results in Mexico and Nepal assessments

Comparing methods and metrics

Similar methods were used in both assessments in Oaxaca and for the HMRP in Nepal. In both cases a mix of qualitative and quantitative tools, participatory assessments, and economic methods (econometric analysis in Oaxaca, Economic Surplus analysis in Nepal, and Gross Margin analysis in both) were used. Both assessments integrate the rigorous use of both the before/after and with/without counterfactuals. The approaches used are summarized in Table 9.

Similar indicators for impacts and changes in livelihoods were used. This set of metrics comprehensively covers and measures outcomes and impacts on livelihoods (Table 10). Using the indicators, we quantified changes in livelihood capitals, in income, in poverty (including food security), in equity, and economic changes such as technology gross margins and economic surplus. The metrics also captured a range of direct and indirect impacts, as well as outcomes. Specific differences in metrics between the studies are due to the different purposes.

Table 9. Comparison of methods in the Oaxaca and Nepal assessments.

Methods	Oaxaca, Mexico	HMRP, Nepal
	Data collection methods	
Key informants, secondary data	Yes	Yes
Focal Group Discussions, PRA	Yes, 3 communities	Yes, 10 communities
Household surveys	Yes	Only observations
	Economic tools	
Econometric analysis	Yes	No
Gross Margin analysis	Yes, 12 farmers	Yes, all communities
Economic Surplus analysis	No	Yes
	Use of counterfactual	
With/without	Participants/non-participants	Participants/non-participants
Before/after	Yes, from 1998 baseline	Partially, recall method

Table 10. Comparative metrics for the Oaxaca and Nepal studies.

Metrics	Oaxaca, Mexico	HMRP, Nepal
Livelihood capitals	Yes, 13 capitals	Social, financial, vulnerability
Income, poverty	Yes, poverty levels	Yes, indirectly
Food security	Not explicitly, not an issue	Yes
Equity (typologies)	4 household typologies (clusters)	Classified into 3 household types according to food sufficiency and social group: dalits, brahmins, janajatis
Gender	In part, both genders responded	Explicitly included
Technology gross margin	Yes	Yes
Economic surplus	No	Yes
	Type of impacts	
	Oaxaca, Mexico	**HMRP, Nepal**
Direct	E.g. maize yield, area, varieties used	E.g. maize productivity, variety use, cost reducing
Indirect	E.g. benefits and use of training	E.g. empowerment, social inclusion, equity

Comparison of results and impacts

The impacts of the Oaxaca Project were mainly positive, particularly in terms of the impact of adopting silos and CIMMYT maize selections. In other respects the impacts were moderate, such as from capacity-building where the effects had partially dissipated by the time the assessment was done. The study proved that the adoption and use of CIMMYT maize selections increased the value of maize production and the contribution maize production made to total income. This contributed to reducing poverty (as assessed according to the household livelihood typologies in this study). The overall findings also suggest that it would have been a good investment for CIMMYT to have maintained a presence on the ground in Oaxaca to strengthen and sustain the technical interventions (silos and capacity-building). This would have made an even more significant impact on poverty reduction.

Achieving livelihood impacts through maize was just *one* of the goals of the project. Other goals were to boost knowledge of maize diversity and to generate and test participatory research approaches. The benefits of these goals, however, are more difficult to quantify in monetary terms. Benefits take the form of a general contribution to the stock of scientific knowledge and were beyond the explicit scope of the Oaxaca impact study. However, the spillover of knowledge on maize diversity and participatory methods developed by the project must also be recognized as part of the overall benefits.

In Nepal the study showed that the improved maize technology is spreading, that demand is growing for improved maize technology, and that maize is playing an increasingly important role in improving livelihoods. But, by 2006, improved maize technology had not yet reached a large number of farmers. Progress had been made in increasing food security and food sufficiency. What is needed now is a strategy to scale up research and development interventions to reach more poor farmers. Mathema and Gurung (2006) estimate that enough maize seed can be produced by the HMRP to expand the reach of the maize varieties developed.

The HMRP guidelines call for 70% of participants to be from the food deficit group, and for more than 50% to be women. These guidelines help to better target future interventions. HMRP incorporated gender, poverty, and social equity issues to improve livelihoods and food security of the poor and excluded groups and, hence, reached out to the most marginalized and vulnerable social and economic groups, the *dalits*, *janajatis*, and the women.

The major policy contribution of HMRP is the work to institutionalize participatory approaches for varietal selection and improved seed production in the hills of Nepal. Many government and non-government organizations, and the national agricultural research system, have adopted these concepts and have a better knowledge of maize varieties, agronomic practices for growing maize, and for producing seed. NARC staff reported that they are more confident in their ability to conduct participatory research because they have become more capable of implementing PVS trials and demonstrating improved agronomic practices. Farmers who participated in the training enhanced their technical skills in maize production, in selecting improved seed, and in post-harvest techniques.

The contrasts between Oaxaca—located in Mexico where maize originated—and Nepal are interesting. In Oaxaca, the study shows only moderate use of improved maize, that the average age of active farmers is increasing (also due to strong migration), that there are declines in the area planted with maize, and that less maize is being grown as a commercial crop. In Nepal, however, the use of improved maize varieties is growing and plays increasingly important roles in improving livelihoods. For instance, the food self-sufficiency of participant in HMRP areas improved from 11% in 2002 to 24% in 2006. This can be partially explained by higher maize yields (and surplus production) in Nepal compared to Oaxaca, although the gross margins are higher in

Oaxaca in absolute terms. Also, while in Nepal maize was initially grown mainly for household consumption, now surplus maize is being sold. Compared to local varieties, the yield and area of improved varieties are increasing. Farmers in Nepal tend to prefer improved varieties, since they grow maize both to sell it at the market and for household food security, whereas in Mexico maize retains its distinct 'cultural' role as a traditional food.

In terms of attributing impacts, the impact pathways of the HMRP in Nepal are clearer and the benefits that can be attributed to CIMMYT and NARC are more explicit. In Mexico, the impacts of the silos intervention can clearly be attributed to CIMMYT. For maize improvement activities, partners' contributions must be recognized. The Nepal assessment showed that intermediaries played key roles in increasing research, extension, NGO, and farmer group capacity. The studies showed that, at farm level, increases in maize yield were greater in Nepal than in Mexico. This was because community-based multiplication of maize seed helped spread the benefits into neighboring districts in Nepal, whereas the same thing did not happen in Mexico.

Concluding remarks

This study provides lessons on assessing impact through a livelihood lens, to capture the impacts of International Public Goods produced by CGIAR centers and partners more broadly. This paper assesses the impact of projects in Oaxaca, Mexico, and Nepal. The two projects targeted relatively marginalized farmers. The projects selected maize varieties, introduced post-harvest technology, provided training, built capacity, disseminated research results, and undertook participatory research with farmers. In the Oaxaca study we tested and piloted new tools for socio-economic and IA research: Personal Digital Assistants (PDAs) for collecting real-time field data from farmers, and Google Earth™ to gather and analyze spatial data.

One general lesson learned for assessing impacts of research projects is that livelihood impacts and changes can be measured more accurately 5–10 years after the project has been completed rather than immediately after project completion. The earlier monitoring studies in Oaxaca (Smale et al. 1999; 2003) were done only a few years after the Oaxaca Project ended. At that time, farmers still had most of the maize varieties selected during the project and the capacity-building was still fresh in their minds. So, the findings of these earlier studies often differ from the findings of the 2006 impact study, conducted eight years after the project ended. By 2006, farmers had lost most of the CIMMYT maize selections (often because of drought) and the effects of capacity-building had dissipated to some extent. This suggests that, by assessing impacts too early, there is a risk that impacts will be overestimated. However, there is also the risk of underestimating impacts because the effects of actions that materialize after more time has passed will not be captured. For example, the impact of silos, facilitated by the Oaxaca Project, was found to be much larger in 2006 than in the late 1990s because the silo technology spread well from farmer-to-farmer after the 1990s. Another implication is that if research projects are to have broader and sustained development impacts the project duration should be adequate to ensure this. For example, while drought in the early 2000s explains to some extent the loss of some of the maize varieties promoted by the Oaxaca Project, had the project maintained a field presence, through partners or the private sector, interested farmers could have still obtained project promoted maize varieties and sustained the impact from adopting maize selections.

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Annex: Spatial data collection and analysis in Oaxaca based on Google Earth™

D.P. Hodson and V.M. Hernandez

Introduction

Geographic information system (GIS) tools, for spatial analysis and the extraction of secondary data relating to the biophysical environment of the study area, were used to collect geo-referenced field data during the Oaxaca study. There were several objectives associated with this component of the project. They included the application of new techniques for field data collection, a characterization of the broader environment in which the study was undertaken, and an exploratory analysis of temporal changes in climate. GIS tools were used to determine the characteristics of maize plots in terms of their physical properties (area, slope, soils, and rainfall) and derived factors, such as market access. The analysis permitted the classification of individual maize plots into broad categories as proxies for land quality for comparison with other socio-economic and welfare indicators. In addition, spatial distribution patterns of an adopted technology—small-scale grain storage silos—were investigated using geo-spatial statistical approaches. The exploratory analysis was undertaken to determine the temporal variation in climatic factors within the study area using a range of available data sources.

Materials and methods

Field data collection

Geo-referenced data were collected in three study communities in Oaxaca using various methods. Hand-held global positioning system (GPS) units were used to obtain the locations of households included in the survey and farms having small-scale grain storage silos. A combination of ortho-photos (1:5000 scale, INEGI) and Google Earth™ images held on a laptop computer were used directly with farmers and key informants (extension agents) to identify the locations of individual maize parcels. Once identified, these parcels were digitized on-screen using ArcView™ (Environmental Systems Research Institute) software and their areas calculated. The use of the high resolution imagery in Google Earth™ allowed farmers or key informants to identify parcels in most instances.

Post-processing and secondary data extraction

All geo-referenced field data were incorporated into a GIS framework (ArcGIS™, ESRI). For each individual parcel the actual areas were calculated and the centroids located. Using these data permitted secondary data to be extracted from existing or generated spatial data layers. The secondary data extracted for each parcel centroid are shown in Table 11.

Table 11. Secondary spatial data of maize parcels.

Data layer	Data type	Scale	Source
Precipitation (P) – 5 month optimal (long-term normal)	raster	2 km2 grid	Corbett and O'Brien, 1997
Potential Evapotranspiration (PE) – 5 month optimal (long-term normal)	raster	2 km2 grid	Corbett and O'Brien, 1997
Ratio P/PE – 5 month optimal (long-term normal)	raster	2 km2 grid	Corbett and O'Brien, 1997
Max Temp – 5 month optimal (long-term normal)	raster	2 km2 grid	Corbett and O'Brien, 1997
Min Temp – 5 month optimal (long-term normal)	raster	2 km2 grid	Corbett and O'Brien, 1997
Elevation	raster	90m2 grid	Jarvis et al., 2006
Slope	raster	90m2 grid	Derived from Jarvis et al. 2006
Soil type	vector	1:250,000	INIFAP/CONABIO, 1995
Topsoil pH	vector	1:250,000	INIFAP/CONABIO, 1995
Market access (travel time)	raster	90m2 grid	Generated by CIMMYT GIS

All climatic variables were obtained from interpolated, long-term, normal monthly climate surfaces developed by Corbett and O'Brien (1997) using ANUSPLIN (Hutchinson, 1997). Daily meteorological station data, used as inputs for surface generation, spanned the period from 1960 to 1991. The proxy for the maize-growing season in rainfed conditions was a five-month optimum climate model, which represented the five consecutive months with the highest precipitation to potential evapotranspiration (P/PE) ratios (that is, with greatest water availability). All climatic variables extracted at the plot level relate to this five-month optimum season.

Market access (travel time) surfaces were generated using the accessibility analyst extension for Arc View 3 (ESRI) developed by Farrow and Nelson (2001). This method creates friction surfaces based on assigned velocities to different road classes and land use types, applies a weighting factor based on slope, and uses a cost-distance algorithm to calculate least-cost travel time to specific locations (markets). In this study actual market locations identified by farmers were used for travel time calculations. The travel speed assigned to different road classes and the weighting factors for slope categories were representative of Mexican conditions (Dempewolf et al. 2001 unpublished). A 4 km/h walking speed was assumed for all areas outside the road network. Road network data used in this study were from INEGI (1995) at a scale of 1:50,000.

Land classification

Using selected biophysical variables from the data described above, individual maize parcels were classified into three land types, 'poor,' 'regular,' and 'good.' The criteria and ranges used for 'poor' and 'good' classifications are shown in Table 12. Parcels having most of the factors of a particular class were assigned to that class; all others were designated as 'regular.'

Point pattern analysis

Geo-spatial statistics were used to determine any significant distribution patterns in the locations where farmers owned small-scale grain storage silos. All farmer residential locations (with or without silos) associated with the project were included in the analysis, and tests for spatial auto-correlation were undertaken using Moran's I statistic. Hot-spot analysis was carried out using the Getis-Ord Gi* statistic for local spatial auto-correlation. All tests were implemented with the spatial statistics component of ArcGIS™ (ESRI).

Temporal precipitation patterns

In order to explore any indications of trends in the short-term, local climate data were compiled from different sources. Daily precipitation data were obtained from three meteorological stations located in the central valleys of Oaxaca (Oaxaca de Juarez, *Aeropuerto,* and Santa Ana Tlapacoyan). Stations were chosen based on the reliability of their data (no missing data in August being a key criterion) that extended over a reasonable period (at least 20 years) and were located close to the study communities. The time periods for the data varied between stations; Oaxaca de Juarez station 1953 to 1997 (incomplete); *Aeropuerto* station 1982 to 2005; and Santa Ana Tlapacoyan station 1985 to 2005 (incomplete). An additional and non-traditional source of daily precipitation data was obtained from NASA's tropical rainfall monitoring mission (TRMM). This is a satellite-based sensor providing three-hourly estimates of rainfall on a 0.25° x 0.25° grid between the latitudes 35N and 35S (NASA, 2006). Data for the study were extracted from the TRMM data archives for the period 1998 to 2006, using daily TRMM (3B42 V6 derived) data products. Daily TRMM precipitation data, averaged over the geographic area of the project sites, were used in the study. Given the critical importance of the August precipitation on maize yields in Oaxaca (Dilley, 1997), the total August precipitation by year was calculated for all datasets of precipitation regardless of their source. We also

Table 12. Land parcel classification criteria.

Type of parcel	Slope	Precipitation	Regimen	Soil PH
Good	‹ 4 %	› 600 mm	Irrigated or rainfed-irrigated	‹= 7.5
Bad	› 4 %	‹ 600 mm	Rainfed	› 7.5

explored indicators of the likely planting date and the year-to-year variations. To develop a potential indicator, standard criteria were applied to TRMM data in the following way. A hypothetical planting date was assumed once daily precipitation estimates were greater than or equal to 3 mm on six out of seven consecutive days. It was also assumed that planting would not occur before 15 May in any year and that the actual planting would occur on the sixth rainfall day. The final aspect concerned the year-to-year variation in moisture patterns associated with critical maize development stages, such as flowering. A rough approximation of the flowering period was determined by adding 60 days to the assumed 'planting' date and then adding/subtracting 10 days on either side of this 'flowering' date. Within this 20-day period, the total precipitation, the number of consecutive days with no significant rainfall (daily precipitation less than or equal to 3 mm), and the absolute number of 'rain days' were calculated. No soil parameters—for example water holding capacity—were included in the study.

Environment and climatic results

A total of 149 individual maize plots were identified, mapped, and classified in the three communities included in the project. It was found that using high resolution Google Earth™ images facilitated the process of identifying and mapping plots. The communities differ in terms of their accessibility to market: San Pablo Huitzo is the most accessible and San Lorenzo the least accessible (Figure 5). A summary of the individual maize plot classifications (using the criteria given in Table 12) by community is given in Table 13 and Table 14.

Using the quality assessment of a farmer's principal maize plot as the criteria, 79% of the farmers who had 'good' principal maize plots were located in San Pablo Huitzo (land quality rank 1), 53% of the farmers who had 'regular' principal maize plots were in San Lorenzo (land quality rank 2), and 50% of farmers who had 'poor' principal maize plots were in Santa Ana (land quality rank 3). These

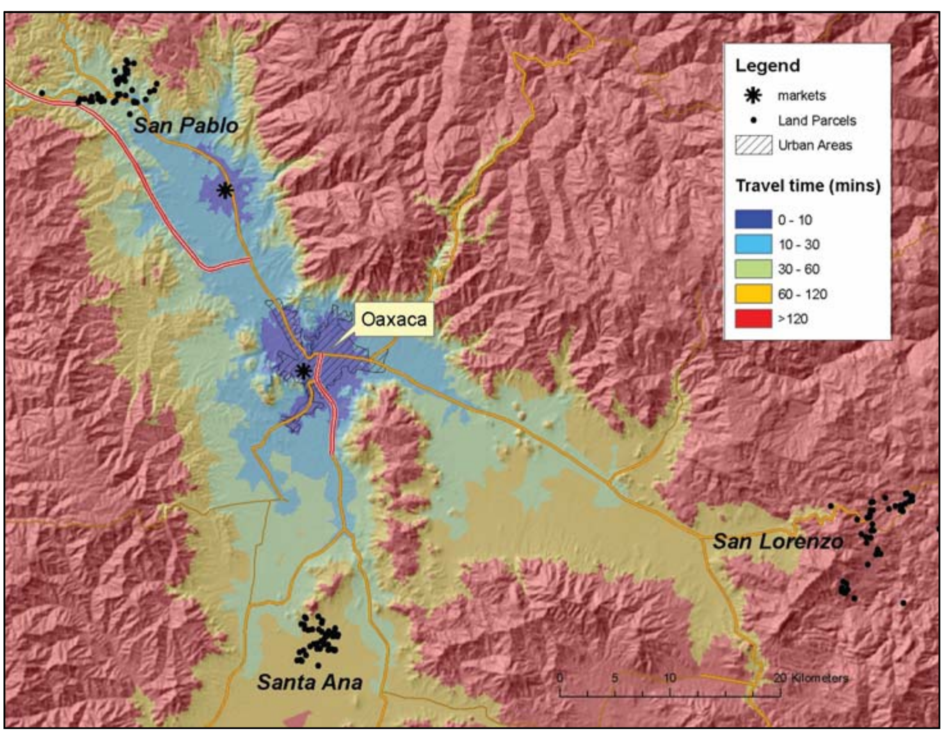

Figure 5. Land parcels and market access in Oaxaca study area, (see color plates inside back cover).

data indicate the differences between the quality of the land and the natural resource base in the three communities. Given these data, we searched for any associations between land indicators and economic status. Indications of economic status for the study communities were obtained from two different sources. An independent study into the geo-spatial dimensions of rural poverty in Mexico (Bellon et al. 2005b), developed a predictive model using small-area estimation methods to estimate the monthly per capita expenditure of the average household by community for the year 2000. Results for the study communities in Oaxaca from the Bellon et al. (2005b) prediction model are provided in Table 15. These data, in terms of community rankings, are in line with data from the land quality assessment i.e., best land quality rank equates to best economic rank and vice versa providing some indication of the potential linkages between the natural resource base and economic status.

Distribution of small-scale grain silos

Farmer ownership of small-scale grain silos was recorded in each study community (Figure 6). A total of 28 silos (12 in Santa Ana, 9 in Huitzo, 7 in San Lorenzo) were recorded for 21 different farmers. A spatial autocorrelation check on the full household dataset (all communities combined) revealed significant spatial clustering of silos (Moran's I, $z = 2.2$, $p<0.05$). At the individual community level, San Pablo Huitzo had a highly significant clustering of households with silos (Getis-Ord Gi* $z = 4.3$, $p<0.01$), San Lorenzo had a significant clustering of silos (Getis-Ord Gi* $z = 2.2$, $p<0.05$), whereas in Santa Ana the distribution of silos was random with no significant clustering observed (Getis-Ord Gi* $z = -0.2$, not significant). The factors driving these observed patterns are unknown, but the patterns might be influenced by such issues as how long silo technology has been available to a community and local information exchange among family members or neighbors, amongst others.

Meteorological station data

Total precipitation data for August from each meteorological station illustrate the local variations in measured precipitation in this region. Figure 7 shows the total August precipitation for the three stations included in the study by year (1982–2005). Although the stations were located within 40 km of each other, in some years there were considerable differences in total August precipitation. For example, in 2003, 154.7 mm were recorded at Santa Ana Tlapacoyan versus 64.1 mm

Table 14. Summary of principal maize parcel characteristics by community.

Community	'Good'	'Regular'	'Poor'	Total
San Lorenzo A.	4	31	10	45
San Pablo H.	15	11	11	37
Santa Ana Z.	0	17	21	38
Total	**19**	**59**	**42**	**120**

Table 15. Predicted monthly per capita expenditure per household and poverty lines.

Community	Monthly Expenditure per capita (MXN, year 2000)	Predicted poverty line*	Economic rank
San Lorenzo A.	457.42	1 (food poverty line)	2
San Pablo H.	515.73	2 (capacities poverty line)	1
Santa Ana Z.	430.79	1 (food poverty line)	3

* As defined by SEDESOL (World Bank 2004); Bellon et al. 2005b.

Table 13. Summary of maize parcel characteristics by community.

Community	Mean plot size (ha)	Min. plot size (ha)	Max. plot size (ha)	'Good' plots	'Regular' plots	'Poor' plots	Total plots
San Lorenzo A.	0.75	0.02	9.73	8	44	2	54
San Pablo H.	0.52	0.07	1.76	14	13	20	47
Santa Ana Z.	0.92	0.24	2.56	0	12	36	48
Total				**22**	**69**	**58**	**149**

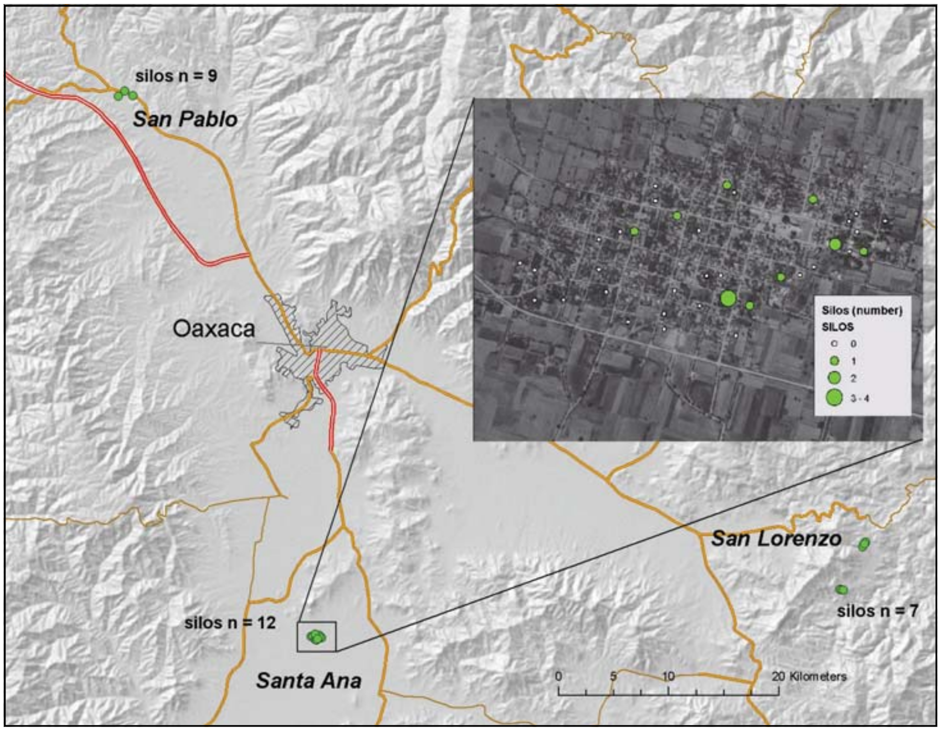

Figure 6. Locations of small-scale grain storage silos, Oaxaca study area (see color plates inside back cover).

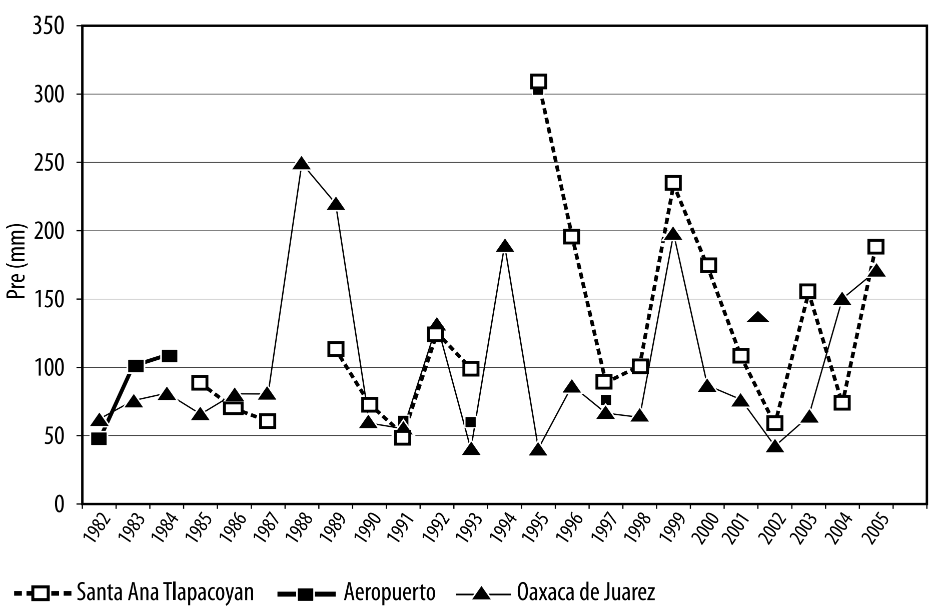

Figure 7. August precipitation, all stations 1982-2005.

recorded in Oaxaca. Very localized showers or thunderstorms, typical of the region, may account for these differences. Even the two stations in the city of Oaxaca recorded within-year differences in August precipitation. It is assumed these were real differences rather than data errors. To deal with this variation, average August precipitation values were used wherever possible. The Dilley (1997) criterion, that an August precipitation of less than or equal to 60 mm is the main negative factor on the rainfed maize yield in Oaxaca, was taken as a proxy for a 'poor' maize year. Table 16 has assumed a number of 'poor' maize years by decade based on available meteorological data[6].

Satellite-derived tropical rainfall monitoring mission (TRMM) data

TRMM data for the period 1998 to 2006 allowed comparisons to be made with meteorological station data. The direct comparison of total August precipitation data from meteorological stations and TRMM revealed some differences. Not surprisingly, TRMM data were not entirely in line with the meteorological station data. Some datasets showed significant differences for the same year, for example 1998 and 2005. Given the different methods of estimating precipitation, and the diverse geographic areas, the differences between the datasets were expected.

More valuable was the standardized nature of the TRMM dataset—e.g. standard geographic units, consistent methodology, no missing data days—and the opportunities for trend analysis within the dataset. Using the criteria described in the Materials and Methods section, the likely planting dates were calculated based on precipitation patterns. Using the likely planting date as a reference point, a critical 20-day moisture stress period, corresponding approximately to maize flowering and based on the known maturity of the germplasm in Oaxaca, was determined and the number of consecutive dry and rain days calculated. The data are summarized in Table 17.

The calculated planting dates varied considerably over the nine-year period, being spread over a four- to five-week period. The earliest calculated planting date was 23 May and the latest was 25 June; the median planting date was 10 June. These dates were in line with expert opinion on the actual spread of planting dates in the area. There appeared to be no consistent trend of increasing earliness or lateness based on the calculated likely planting dates. Figure 8 shows data on the longest dry spells and the number of rain days for the critical 20-day 'flowering' period. Linear trend lines fitted to the data indicate that dry spells tend to be longer and, conversely, that the number of rain days is decreasing. Trends for August and 'flowering' precipitation are shown in Figure 9. The TRMM

Table 16. Assumed 'poor' maize years by decade based on August precipitation data.

Decade	Poor maize years per decade (August precipitation <= 60 mm)	Comments
1950s, 1960s	2 (in both decades)	Oaxaca station only
1970s	3	Oaxaca station only
1980s, 1990s, 2000s	1 (in each decade)	2-3 station average

Table 17. Calculated likely planting dates and flowering period data, from TRMM.

Year	Calculate planting date	Consecutive. dry days*	Total dry days**	Total precipitation***
1998	11 June	5	7	91.4
1999	25 June	4	12	130.5
2000	25 May	5	4	45.2
2001	4 June	8	8	93.0
2002	10 June	5	7	53.3
2003	8 June	13	2	31.0
2004	13 June	8	5	58.8
2005	23 May	6	8	72.3
2006	20 June	10	3	34.5

Maximum number of consecutive dry days (< 3mm)
** Total rain days (>= 3mm)
*** Expressed in (mm) for the derived 20-day flowering period

6 This rapid assessment is supported by recent data, as the maize growing seasons of 1998 and 2006 were both below average in terms of rainfall and maize yield, i.e. matching the poor year per decade in Table 16.

data appear to show a trend for precipitation to decrease over time in both cases. A similar trend was observed for the precipitation in the growing season (i.e. total rainfall from calculated planting date to end of October) estimated from TRMM data (data not shown). However, it must be noted that a similar, consistent trend of decreasing August precipitation was not apparent when averaged meteorological station data were used instead of TRMM data.

The conflicting nature of the climatic indicators in this study indicates that more rigorous research would be needed to determine whether or not farmers' perceptions of a worsening climate have any scientific basis. On the one hand, some indicators seem to support the notion of a worsening climate as perceived by farmers in the focal group discussions (FGDs). But, on the other hand, other indicators, for example the decreasing frequency of 'poor' maize years per decade, contradict perceptions expressed in the FGDs. Several factors might account for this. For example group perceptions are notoriously biased toward recent, short-term events. In addition, group participants tend to frame their responses to questions to correspond with the perceived 'interest of the interviewer,' or with views expressed by the popular media. These factors potentially bias the results. On the other hand, despite this potential bias and subjectivity, farmers' perceptions are very valuable and often have a sound basis.

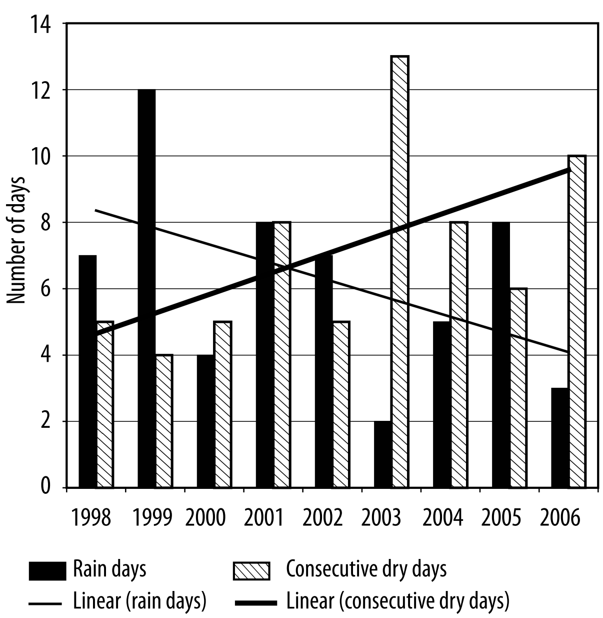

Figure 8. Derived moisture indicators (maximum number of consecutive dry days and number of rain days) during maize 'flowering' and trends during 1998–2006.

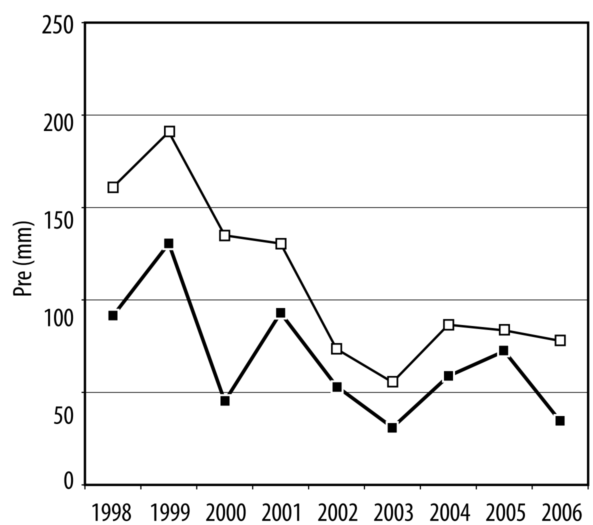

Figure 9. August and maize 'flowering' precipitation estimate – TRMM data 1998.

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