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The economic costs and benefits of a participatory project to conserve maize landraces on farms in Oaxaca, Mexico☆

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Abstract

Conventional methods were used to assess the benefits and costs of an unconventional project whose purpose was to test whether participatory crop improvement can encourage Mexican farmers to continue growing maize landraces by enhancing their current use value. Findings suggest that farmers as a group earned a high benefit–cost ratio from participating, though from the perspective of the private investor the returns were low. The project also generated social benefits, but these would be difficult (and costly) to measure. There was a gender bias in both participation and benefits distributions, though there is some evidence of a welfare transfer to maize deficit households. Application of other valuation approaches will be necessary in order to assess both the private and social benefits of similar projects.

Keywords: Maize; On-farm conservation; Participatory plant breeding; Costs and benefits; Mexico

1. Introduction

Genetic stocks maintained on farms are renewed only as long as farmers plant them. If, as economies develop, modern types become more attractive relative to landraces, rare genes may be 'lost' to future generations unless special efforts are made to collect them or to encourage continued cultivation. The purpose of the project assessed in this article was to test the hypothesis that participatory crop improvement can encourage Mexican farmers to maintain maize (*Zea mays* L.) landraces by enhancing their current use value. By current use value we refer to the utility farmers gain today by growing landraces, whether they are subsistence-oriented or maximise profits.

There are reasons why it makes sense to test this hypothesis in the Central Valleys of the state of Oaxaca, Mexico. First, Oaxacan farmers demand maize landraces for their production attributes. The maize landraces that compose the Bolita racial complex are known for their tolerance to the *canícula*, a droughty period in the middle of the growing season, as well as for other traits related to agronomic performance

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(Wellhausen et al., 1952). Certain alleles[1] or combinations of different alleles in the complex enable farmers to cope with drought stress. Second, modern maize types cannot compete with local landraces except under irrigated conditions, which represent only 5% of the maize area in the study regions (INEGI, 1996). Landraces continue to dominate the maize area. Third, in places like Oaxaca, 'cultural autonomy' (Brush, 2000) reinforces consumer demand for landrace attributes. Where culture is of great historical importance and numerous indigenous languages are still spoken, diversity in colour, texture, and form of maize products reinforce the role of farm families as members of their communities. Recently, new methods applied to archaeological findings from a cave in Oaxaca indicate that maize has been not only cultivated but also consumed there as food for 6250 years (Brown, 2001).

Participatory crop improvement is one of a number of strategies that have been proposed for enhancing the current use value of landraces to the farmers who still grow them. For example, adding specific traits or improving yield performance may enhance current use value. In the work presented here, we attempted to analyse the costs and benefits of the project by applying conventional concepts. Below, we (1) summarise project activities; (2) characterise the extent, intensity and equity of participation; (3) estimate the economic benefits and costs to farmers as well as from the perspective of an investor; and (4) describe their distribution among social and economic groups. Conclusions are drawn in the final section.

2. Project phases and activities

The participatory phase of the project, analysed here, follows a first phase (1997–1999) with a primary goal to improve the potential value of Bolita materials stored in ex situ collections. Expert farmers in the study region donated samples of 152 outstanding maize landraces. To evaluate the agronomic performance and characterise the morphological diversity of these materials, researcher-managed, on-farm trials were established in all 15 communities from which collections were made.

The diversity of the maize landraces collected in situ was assessed with the same techniques used to identify core subsets in ex situ collections (Franco et al., 1997). Several of the materials that performed well on station and in researcher-managed, on-farm trials were then selected for improvement and further evaluation. During this period, six field days were organised so farmers from the communities could view the trials when the maize plants reached physiological maturity and at harvest. Farmers were asked to 'vote' for the maize landraces that most attracted their interest. Based on the data from the agronomic evaluations and farmers' expressions of interest, 16 landraces and one improved variety were chosen for the second phase of the project. Given the process by which they were selected, we refer here to these materials as 'elite landraces' (Bellon et al., 2003).

During this period, social scientists working with the project also selected a subset of six communities from the original 15, based on contrasts in the productivity potential of maize and the relative importance of farm and non-farm sources in household income. In the six project sites, they implemented a baseline survey with a random sample of 240 households.

The analysis presented next treats the costs and benefits of farmer participation as those borne and experienced directly by farmers only during the second phase of the project (1999–2002). Farmer participation is evaluated in local currency (Mexican pesos, MX$) since the costs and benefits involved non-traded, local goods and services. The economic costs and benefits of the project as a whole are considered separately, calculated differently, and expressed in real US dollars (US$).

3. Farmer participation in the second phase of the project

The nature of the participatory research in the Oaxaca project has been explored in depth by Bellon (2001) and is treated simply here. All farmer participation was voluntary, following an open invitation and publicity by local contacts, extension personnel and project staff. To the extent possible, project activities

[1] Variants of the same gene are called alleles. A gene is a section of DNA that codes for a specific biochemical function. Genes are the functional unit of heredity.

were organised to minimise conflicts with farmers' (both men and women) other responsibilities.

There were several types or 'intensities' of participation. The lowest intensity involved attendance at field demonstrations that lasted only a few hours. A second type of participation occurred when farmers chose to purchase the seed of diverse, elite landraces that was offered by project staff. In a third type of participation, field staff helped to establish experiments with a small set of farmers who expressed scepticism at the demonstrations but were motivated to try new seed types. Farmers in this group participated by growing small amounts of seed of three elite landraces alongside their own 'control' (typically the landrace they grow on a regular basis) and managing them with usual practices.

The fourth and most intensive type of participation was attendance at training sessions conducted by the field staff. Results from the first phase of the project showed that farmers' storage and selection practices were not meeting their needs. We identified important knowledge gaps associated with these practices, such as the lack of understanding of maize reproduction, use of small quantities of ears to select seed, and inadequate storage. The training sessions addressed these gaps with general principles and simple techniques. The first three sessions, conducted in 1999, dealt with perceptions of maize crop reproduction and principles of mass selection. The last two sessions, held in 2000, involved principles and techniques of storing maize seed and grain. Finally, some farmers both purchased seed and attended training sessions. It was hoped that certain seed selection and storage methods could serve to maintain the advantages that elite maize landraces represented over those usually grown.

4. Extent, level and equity of participation

Oaxaca is the third most economically marginal state in Mexico, succeeded only slightly by Guerrero and Chiapas (CONAPO, 2000). In general, communities in the Central Valleys are less economically marginal than those located in the mountains, and the project sites as a group are less marginal than the state of Oaxaca.

In 1999 and 2000, 959 different farmers were directly involved in the project in some way (Table 1).

Table 1
Numbers of farmers by intensity of participation, 1999–2000[a]

Type of activity	Number of farmers		
	1999	2000	Either year[b]
Visits to researcher-managed demonstrations	209	296	495
Seed purchase	120	210	287
Farmer-managed experiments	23	0	23
Participation in training sessions	509	409	740
Both seed purchase and training	68	75	170
Total number of farmers participating in any one of the activities	638	617	959+

[a] Source: CIMMYT Project Monitoring Survey, Central Valleys of Oaxaca, Mexico.

[b] Some farmers participated in more than one activity, so column totals exceed the total number of participants. In 2001, 121 farmers also purchased seed.

Nearly 500 farmers attended field demonstrations in 1 year or another. In 1999, 120 farmers purchased a total of about 804 kg of seed (6.7 kg/farmer), increasing to 210 farmers and 1083 kg in 2000 (5.2 kg/farmer). Around 923 kg were sold to 121 farmers in 2001 (7.6 kg/farmer), although these sales were not planned. At an average seeding rate of 16 kg/ha, this amount is equivalent to about 176 ha of maize in total. Purchased seed would have been planted to 9–14% of the average farmers' maize area of 3.5 ha. Of the 30 farmers who expressed interest, 23 actually evaluated materials on their farms in the first year. During 1999, 509 farmers attended the three training sessions. In 2000, 409 farmers participated in two sessions. Of those who purchased seed, 170 were also involved in training sessions in either of the 2 years.

Equity in the likelihood of project participation is indicated by the percentage distribution of the farmer participants by wealth status, gender and other social and economic characteristics, compared to the baseline random sample survey of 240 households. There was no evidence of wealth bias in project participation, nor is there evidence of any systematic relationship between level of participation and level of wealth. The distribution of participants by the wealth rank of their households (method detailed in Bellon, 2001) did not vary in an important way by type of activity, and reproduced fairly closely the distribution found in a random sample of households (Table 2). The largest group in each case is composed of farmers from households

Table 2
Distribution of participants by household wealth status, compared to project baseline, 1999[a]

Type of activity	Group size	No. ranked[b]	Rich	Percentage of households		
				Intermediate	Poor	All
Demonstration visitors	209	172	24	48	28	100
Seed purchasers	120	94	30	43	27	100
Farmer experimenters	23	21	29	48	23	100
Training session participants	509	324	19	53	28	100
Seed purchasers and training participants	68	56	27	45	28	100
All 1999 participants	638	423	21	53	26	100
Baseline sample of farm households	240	239	20	57	23	100

[a] Source: CIMMYT Project Monitoring Survey, Central Valleys of Oaxaca, Mexico.
[b] Of all 1999 participants, 66% were ranked. Households of participants, rather than individual participants, were ranked.

Table 3
Comparison of male and female participants by wealth status of household, 1999–2000[a]

Type of activity	Total no.	No. ranked[b]	Rich	Percentage of households		
				Intermediate	Poor	All
Male participants	623	357	23	56	21	100
Female participants	283	97	6	45	49	100
Baseline sample of farm households	240	239	20	57	23	100

[a] Source: CIMMYT Project Monitoring Survey, Central Valleys of Oaxaca, Mexico.
[b] The null hypothesis that men and women participants are drawn from the same underlying distribution with respect to wealth was rejected with a χ^2-test at a significance level of 0.01.

ranked as intermediate in wealth, with the remainder split fairly evenly between rich and poor. A χ^2-test of independence failed to reject the null hypothesis that the two classifications of level of participation and wealth rank are independent.

There was, however, an evident gender bias in project participation. In any category, over two-thirds of participants were men. Data cannot be compared to the baseline survey because both men and women in each household were deliberately interviewed for a 50:50 representation. The census data for the state of Oaxaca (INEGI, 2000) show that the ratio of women to men slightly favours women (52% compared to 48%). In one of the communities, Santa Ana Zegache, there was a much higher participation by women. CONAPO (2000) ranks the municipality of Santa Ana Zegache among the most marginal in the state and in Mexico. Gender is clearly related to wealth status among participants (Table 3). While the distribution of men reflects the distribution of the population as a whole, the distribution of women is skewed in favour of poor households. Women who are involved in the project are more likely to come from poorer households.

Comparisons of age distributions between project participants and INEGI data indicates that the project favoured the age groups from 25 to 79 years, and disfavoured the age group from 15 to 24, relative to the population in the municipalities included in the project (Solano and Martínez, 2000). While this finding makes sense given that young people are less likely to farm independently, it is indicative of a general problem afflicting not only the Central Valleys of Oaxaca but other rural areas in the nation, where the majority of farmers are older than 60 years of age (Ortíz, 2000, based on INEGI data).

5. Costs and benefits of farmer participation

The costs and benefits we estimated include private values that can be measured or imputed in monetary terms and scores that represent utility indices

Table 4
Estimated average per farmer and total net benefits of participation in project, 1999–2000[a]

Level of participation	Experimenters	Level of participation			All levels
		Seed purchase only	Training only	Seed purchase and training	
Farmers participating from 1999	23	53	442	67	585
Cost of participation per farmer	171	8	203	230	157
Benefits of growing elite rather than other landraces:					
Value of additional grain	170	165	0	73	195
Value of additional fodder	261	314	0	47	213
Benefits of adapting practices	0	0	0	0	0
Net benefits of participation, including fodder and grain	259	471	−203	−110	250
Net benefits of continued use of seed in 2000 and 2001	413	413	0	413	221
Subtotal net benefits	15456	46849	−89509	20299	275868
Additional farmers participating in 2000	0	109	186	32	327
Net benefits of participation and use of seed 2000–2002		630	−39	529	373
Number of farmers	0	109	186	32	327
Subtotal net benefits		68703	−7219	16927	122130
Total net benefits of participation	15456	115552	−96728	37226	397999

[a] Source: CIMMYT Project Monitoring Survey, Central Valleys of Oaxaca, Mexico.

associated with landrace traits. Calculations were based on a monitoring survey of 142 of the participants.

Costs of participation can also be viewed as farmers' willingness to invest in the project. The average marginal cost of participation, or investment per farmer, closely follows the levels of participation or 'intensity' described above (Table 4). Though the highest cost per farmer was borne by those who made investments both in terms of time in training sessions and seed, the highest total cost per group was borne by training participants since they were more numerous. Those who only purchased seed invested least. The level of investment of experimenters was closer to that of trainees.

By all appearances, farmers wanted the seed more than the practices. Technicians' records and farmers' reports show that participating farmers managed the elite landraces in the same way as the maize landraces they usually grow. Among the samples of farmers who purchased seed of elite maize landraces, with or without attending training sessions, the average difference in production costs of only MX$ 7.40 was composed almost entirely of the difference in seed costs (sold at production cost of MX$ 5/kg vs. an average for other landrace seed of MX$ 3.42/kg).[2]

Very few of the participants applied practices learned at the training sessions to either elite landraces or those they usually grow. The average investment per farmer in applying practices discussed in training sessions, in terms of both labour and cash, was MX$ 72. Overall, attendance was lowest for sessions on selecting and marking superior plants. The entire cost of applying improved seed selection practices was borne by farmers in terms of their time, and farmers surveyed often referred to the time costs of employing such practices as prohibitive. Only two or three farmers stated that they had used such practices, out of a total of 52 surveyed in this group. Cash outlays, rather than time, are the major cost of adopting recommended storage practices. Only two or three of the participants surveyed were willing to make the cash investment in a new silo.

Cost estimates reported here depend heavily, in absolute magnitude, on the imputed wage rate for farmers, though we know little about how labour markets work in these communities. Baseline and monitoring surveys confirm that most farmers work off their own farms, on other farms, in local non-farm employment in the community, or occasionally as migrants. The value of their time is determined by many factors and is likely to vary widely. The daily wage reported in our survey represents about 6 h of adult male labour for planting or weeding. Sample data indicates that the daily wage rose by 47% between 1999 and 2000,

[2] The MX$–US$ exchange rate averaged 9.6–9.7 over the 1999–2001 period.

from about MX$ 45–66 per day, and by a similar percentage between 2000 and 2001. This abrupt increase, which farmers themselves reported with amazement, appears to reflect a number of factors. Several garment assembly plants have recently been established nearby. According to technicians, disease in the agave species, commonly utilised to produce tequila, has led to a shift in the demand by tequila manufacturers toward the locally grown species, and to local labour required to extract the plants. The rate of migration out of these communities may also be increasing, and several of the participants sampled could not be interviewed because they had migrated to the USA.

The finding that farmers who invested more in terms of time in training sessions bore the largest share of project costs is likely to hold for any reasonable assumption concerning the value of the time, since (1) differential seed and production costs between elite and usual landraces were negligible and (2) application of new practices was rare. Total estimated investment by farmers in 1999 and 2000, or the total cost of farmer participation, was roughly MX$ 140,000.

The value of total net private benefits to farmers is an indicator of whether farmers as a group were compensated for their investment. Yield estimates were obtained from experimental data (reported in Smale et al., 1999), official data (INEGI, 1996–2000), and farmers, using recall, crop-cuts of subplots (Casley and Kumar, 1988), and expected yields based on elicited triangular distributions (Hardaker et al., 1997). Actual yield advantages (or disadvantages) were used to estimate benefits from growing elite landraces in the initial year. Survey data suggest that the level of secondary distribution to farmers roughly equalled the discarding and loss of new seed by primary users, so that the average area per participating farmer was similar over the years. For the second and third years of the project, benefits were therefore estimated by applying the sample mean yield advantage (14.5%) multiplied by the expected yields calculated from farmers' subjective yield distributions by average area planted per participant.

Though the yields for the same material vary widely under farmers' conditions in the Central Valleys, and differences in sample means were not statistically significant, the yield advantage of elite landraces is supported by two other findings. First, the elite landraces were selected by breeders based on a complete biometric evaluation of data from on-farm and on-station trials (Taba et al., 1998). Second, the pattern of farmers' votes during demonstration days conformed closely to the landraces selected by maize breeders (Bellon et al., 2003). Since elite landraces are the same in genetic structure as other landraces, their yield advantages do not decline over seasons, as would be the case with maize hybrids or improved open-pollinated varieties if the seeds were not replaced.

Determining the appropriate price to value yield advantages was not straightforward. The majority of the participating households produce more than they consume in most years, and it seems that households have access to maize grain, since there are frequent exchanges among farmers and an official maize marketing outlet in all but one community. However, Taylor et al. (1999) argued that information problems lead to prices for maize that are community-determined and higher than the national price, and to transaction costs between the community and larger towns that buffer the effects of changes in the national price. Furthermore, though there is a long history of local markets in Central Valleys of Oaxaca (Malinowski and de la Fuente, 1982), the volume of maize landraces traded in these markets is low. We therefore treated maize prices as endogenously determined.

Selling prices were higher than the consumer price in both the monitoring and baseline surveys. Cheap maize was available in all communities except Santa Ana Zegache through the national agency (DICONSA), which sells lower quality mixtures as subsidised grain to maintain a low rural consumer price. Some farmers buy it for their livestock; others who are net consumers are obliged to buy it as a last resort unless they can obtain it more cheaply from relatives or friends. When local farmers sell maize, it is the grain of their own maize landraces, which earns a quality premium. Since it is likely that our prices reflect a mixture of these factors, we chose to use a price averaged over all sample observations to value the production benefits or losses of farmers, regardless of whether they typically produce more or less maize than they need.

Farmers are both producers and consumers of maize in these communities and typically care about attributes other than grain yield. Some landraces produce more or better fodder; others are better suited to the preparation of a traditional dish, such as those that are of major cultural significance in Oaxaca. We used a simple scoring method to elicit preferences from farmers, and adapted a method developed by Reed et al. (1991) to tabulate a landrace 'attainment index' for each landrace and farmer. The index summarises the extent to which each landrace supplies the attributes demanded by the farmer who grows it.

On average, the attainment indices were not significantly different for elite landraces and other landraces grown by farmers. It must be remembered, however, that while farmers have grown their 'control' landraces for many seasons and know their attributes well, they were only able to observe the attributes of elite landraces over one or two seasons. Furthermore, a composite index is a blunt instrument for comparing landraces according to specific attributes. One attribute that 44% of participants cited as very important is fodder quality, and the prices paid for fodder in the project communities are high. The data we have suggest that one of these elite landraces (VC-152), recognised by both breeders and farmers for its fodder potential, yields at least 50% higher than the maize landrace control. For the purposes of benefits estimation, we valued a tercio (local measurement unit for fodder) of dry fodder at the average price cited by farmers of MX$ 19.52 per tercio, and used a yield advantage of 50% for those farmers growing VC-152.

Included in the net private benefits shown in Table 4 are the average value of yield differentials for grain and fodder, though the benefits from adapting practices recommended in training sessions are recorded as zero to reflect their very low incidence. Participation in training sessions is therefore entered solely as a cost. Of all participants, seed purchasers benefited most, on average. They devoted the least in terms of time, though many of them benefited from some yield advantages at negligible extra production cost. Projected earnings for 2000 and 2001 for farmers participating from 1999 and for those who began in 2000 have been included. These earnings are based on estimates for farmers who participated earlier with less time invested in training and a 7% expected increase in prices predicted in our sample data. Total net benefits of participating in the project were estimated at roughly MX$ 398,000.

6. Distribution of costs and benefits

The welfare impacts of seed technological change in closed economies have been modelled and documented in the literature (Pinstrup-Andersen, 1977; Renkow, 1994). In the Oaxaca project no seed technological change has occurred, and we expect no long-term changes in the economic welfare of the groups identified in the literature.

In Table 5 we use the sample data to contrast the short-term investments made and gross benefits earned by the social and economic groups in the study area during the lifetime of the project. Categories are defined by wealth rank of household, gender and several other parameters that represent the theoretical basis on which social welfare analyses of technology impact in developing country agriculture are often conducted. Each category represents a different way of partitioning or 'slicing' the pie of total net benefits among participants. The distribution of total net benefits by category provides information about the project equity.

While farmers from households ranked as intermediate in wealth bore most of the investment costs, they earned the same share of the total benefits as farmers from rich households, constituting a transfer to richer households. Participants from poorer households earned roughly the same proportion of the total benefits as they invested. Gross benefits per farmer declined with wealth status.

The inequities between men and women are reinforced by gross benefits. Gross benefits per male farmer were about twice that for females, probably because men also invested more in purchased inputs compared to labour. The total share of benefits earned by men appears to have been greater than their share of the investment, suggesting a net transfer from female to male participants.

Producers of a maize surplus for food and feed bore a larger share of total project costs; however, a greater share of gross benefits was earned by households that typically produce less than they need. This represents a recognisable welfare transfer from maize surplus to maize deficit households. Maize deficit households earned nearly 2.5 times per capita compared to maize surplus households, though they invested less.

Farmers who feed livestock for sale invested more per capita than those who did not and earned higher gross benefits per capita. Their share of benefits was

Table 5
Estimated total costs and benefits to farmers of project participation, by social and economic group[a]

Group	Costs (MX$)			Benefits (MX$)		
	Per capita investment	Estimated total	Group share of total	Per capita benefits	Estimated total	Group share of total
Wealth rank of household						
Rich	112	31257	22	457	225932	42
Intermediate	172	81843	58	272	231312	43
Poor	116	26845	19	168	80690	15
Gender of participant						
Female	120	28370	20	272	69931	13
Male	154	111576	80	457	468003	87
Food and feed consumption status						
Net surplus of maize, food and feed	163	89434	64	187	209794	39
Net deficit of maize, food and feed	122	50511	36	447	328140	61
Labour status of household						
Net surplus of family labour	131	68099	49	328	328140	61
Net deficit of family labour	163	71846	51	247	209794	39
Livestock production						
Feed livestock for sale	137	116287	83	306	430347	80
Do not feed livestock for sale	184	23664	17	276	107587	20
All groups	204	139945	100	291	537934	100

[a] Source: CIMMYT Project Monitoring Survey, Central Valleys of Oaxaca.

similar to their share of costs. Finally, a small shift also appeared between labour surplus and labour deficit maize producers. Participants from households with sufficient family labour for maize production earned a larger share of gross benefits than those who hire labour for maize production, though there was no difference between them in relative share of costs. One possible explanation is that labour surplus households generate higher yields than those who need to hire labour but are financially constrained. For these labour surplus households, estimated gross benefits from grain are, on average, nearly three times higher than for those who hire labour. Their estimated gross benefits from fodder are more than threefold higher, due to the subset of this group that grew the elite landrace with superior fodder yield (VC-152).

7. Project costs and benefits

Table 6 summarises private costs and benefits from the perspective of both the farmers who participated and a private investor. Not all of the costs incurred in the two phases of the project are considered. The landrace selection, breeding and evaluation activities, together with the site selection, diagnostic and baseline activities of the first phase contributed directly to the design and implementation of the second phase,

Table 6
Project benefit–cost summary, 1997–2000[a]

Category	Nominal (MX$)	Discounted, 1995 (US$)
Farmer benefits of participation[b]	537934.00	27295.00
Costs		
Farmer costs of participation[c]	139945.30	7116.00
Project investment costs[d]		308693.00
Farmer benefit/cost ratio	3.84	3.84
Project benefit/cost ratio		0.09

[a] Source: CIMMYT Project Monitoring Survey, Central Valleys of Oaxaca, Mexico.
[b] Benefits were calculated in nominal MX$, deflated, and converted to US$ at the annual exchange rate.
[c] Costs were calculated in nominal US$ and deflated. A discount rate of 5% is applied.
[d] Project investment costs included maize collection and evaluation of first phase, field staff salaries, operating expenses, training, seed distribution and monitoring.

and are considered here as project costs. Collection and evaluation costs of the first phase of the project are estimated at US$ 61,333, including the time of the senior maize breeder, an international scientist. The costs of implementing the experiments, field days, baseline and monitoring surveys, and seed dissemination, as well as the salaries of all field staff employed by the project, are included for 1997–2001. Field staff consisted of a 3-year post-doctorate student with an international salary, who managed the project; more than five national technicians with advanced training; and a data entry specialist. Other field and local office expenses were also included. Seed was sold at the same local price for good quality landrace seed (MX$ 5/kg). Some capital expenditures were excluded because they were shared with other projects or incurred for other purposes. Institutional overheads were not included. The salary and research expenses of the international scientists who have been only intermittently involved with the project, such as the population geneticist, the human ecologist and the economist, are largely incurred in the generation of methods and knowledge consumed outside the project site by the scientific community of which the lead institution (CIMMYT) is a member. The benefits from methods development cannot be assessed in currency equivalents with the data available here, since they take the form of a contribution to the stock of scientific knowledge, which is a public good.

Total project costs carried from the previous phase plus those incurred in the second phase are estimated at about US$ 308,653 (in US$ 1995). The *private investor* benefit–cost ratio for the project years alone is a mere 0.09; benefits are a fraction of the cost. Assuming (1) the optimistic 14.5% yield advantage estimated from the survey data, (2) a favourable 5% discount rate, and (3) the current real price of maize in the communities as a long-term average (rather than the considerably lower, long-term world price for maize), farmers' use of elite landrace seed would need to increase at an annual rate of 19% to cover all of the costs included in the original project budget. Such an annual rate would be quite optimistic under the circumstances.

Two obvious issues are raised by these results. First, a participatory project that has a relatively large (international) research component and requires resources in addition to those that participants themselves can provide is not likely to generate an overall economic rate of return that is as impressive as most of those estimated for agricultural research and crop breeding. That is not to say that farmers' time is wasted, however. On the contrary, the yield benefits generated by the elite landraces, when compared to the time and other resources invested by farmers, produces a farmer benefit–cost ratio of 3.8!.

A second point is that, unlike a professional maize-breeding organisation, the project did not have germplasm enhancement as an exclusive goal. The goal of the project was to ascertain whether farmers could be encouraged to continue growing landraces through participatory activities designed to enhance their benefits. The answer to that question is 'yes', with the caveat that seed exchange of elite landraces and/or diffusion of silos can be sustained beyond the lifetime of the project investment. While the degeneration in yield that occurs with successively plantings of improved maize types may not occur with elite landraces, future benefits streams for farmers still require investment designed to circulate 'different' maize types among communities.

The potential social benefits of the project are likely to far outweigh the private benefits, though expressing them quantitatively is difficult with the data available to us. These benefits include impacts on maize genetic diversity and reduction in health risks associated with chemical application to stored maize when hermetic silos are used. As this project progressed and scientific understanding of maize landraces in the study region grew, emphasis shifted from breeding new genotypes to distributing elite landraces among communities and maintaining landraces through improved seed management. Landraces in this region exhibit a high rate of deleterious mutations, or random changes in the DNA that may have a negative impact on their performance, and these tend to accumulate over time. By augmenting gene flow among communities, the probability is reduced that the two copies of the same mutation are found and the mutation expressed (Pressoir and Berthaud, 2001). Yield is not increased so much as the expression of undesirable mutations is mitigated. Mexican farmers themselves continually introduce germplasm through seed exchanges and mixing. The project reduced the cost of access to the diversity, and this is likely to generate both private and social benefits.

8. Conclusions

The balance sheet for the project is clear in terms of private benefits. First, the decision to participate in the project appears to have no association with wealth or other social and economic characteristics. However, there was an obvious gender bias in participation: women were far less likely to participate than men, and those who did were more likely to be poor.

Second, for farmers as a group, participating was well worthwhile. Seed purchasers benefited most. The total estimated net benefits to farmers of participating in the project are MX$ 398,000, with a benefit–cost ratio of nearly 3.8–1. Participants from richer households earned a larger proportion of the total than they invested, constituting a net transfer from those classified as intermediate in wealth, who were the biggest investors. The gender bias of participation was reinforced by the distribution of project benefits, since men appear to have earned an even larger share of the benefits than is represented by their investment. While farmers who produce a surplus of maize paid more of the costs, deficit-producers earned a larger share of the benefits.

From the viewpoint of a private investor, project benefits were but a fraction of the costs. All benefits are earned locally, though costs were incurred both locally and internationally, including the time of senior scientists. Though benefits from the diffusion of elite landraces are the only economic gains that can be tallied against project investment, germplasm enhancement was by no means the principal goal of the project. Furthermore, social benefits associated with the project cannot be assessed with the tools at hand. Other approaches are needed to measure the social impact of such projects, but it is also likely that they will rely at least partially on public funding.

A more urgent question that emerged during this work is whether farmers in the Central Valleys of Oaxaca will continue to grow maize at all. Rising wages are a major factor underlying the high cost of maize production per hectare, with family labour costs responsible for about half of the average budget and hired labour representing a large portion of cash expenditures. Grain production alone is unlikely to be profitable. Maize production may remain profitable by a reasonable margin for some farmers, however, if the actual yield and value of fodder lie anywhere near our crude estimates. Since most farmers have livestock to feed for their own use, if not for sale, this hypothesis bears further investigation.

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